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APRIL 1960

VOLUME 3 NUMBER 22

MONTHLY 3/6

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SPECIAL FEATURES

Computers Applied

At the I.Mech.E. last month a large attendance of old and young engineers discussed prospects and present practice. CONTROL reports some of the exchanges

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Analogue-computer Analysis of Rolling-mill Controls—2

R. B. LARKINSON concludes that analogue computers will find general use, and this view is supported in a CONTROL report of last month's S.I.T. lecture by A. H. DOVETON and K. C. W. PEDDER

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Load Cells in Industrial Weighing—3

Dr. R. B. SIMS of Davy-United details some more of the errors that can crop up, and summarizes the installation requirements

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Nucleonic Measurement of Level—2

The main disadvantage is relatively high cost, says E. P. JONES of Isotope Developments, but—paradoxical though it may sound—appreciable economic saving is possible on certain plant

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Hydraulic Servos—C

English Electric's P. D. BOYER discusses the servo-valve, non-linearity (which he thinks is overrated), pressure compensation, power saturation, and actuators

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Digital and Hybrid Simulation Techniques

R. J. A. PAUL of the College of Aeronautics joins forces with M. E. MAXWELL of Short Bros. & Harland to describe a method for synthesis of non-linear functions

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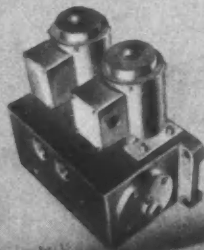
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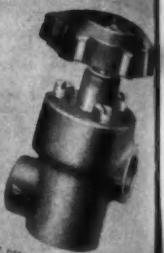
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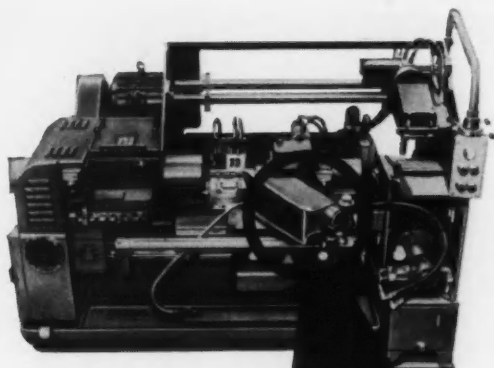
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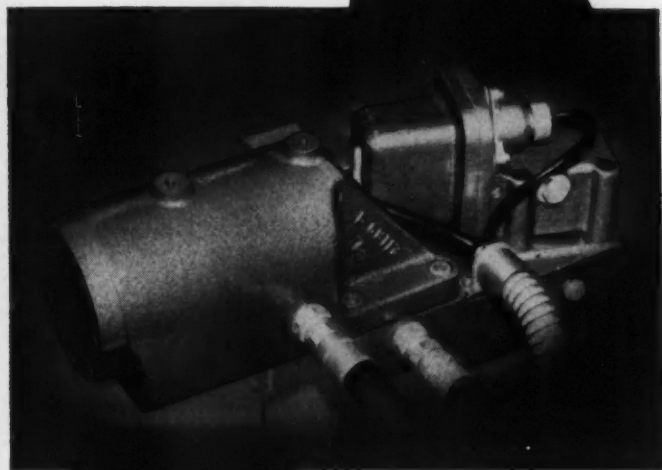
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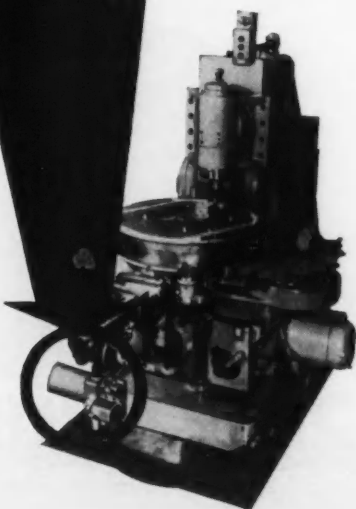
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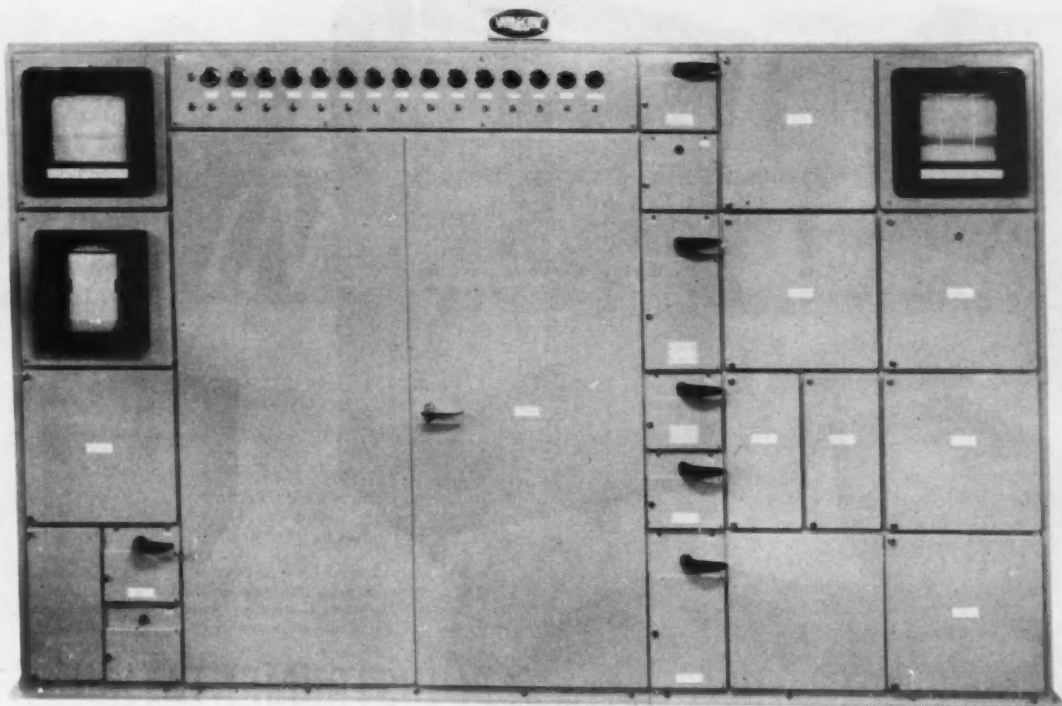
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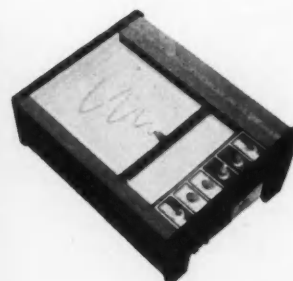
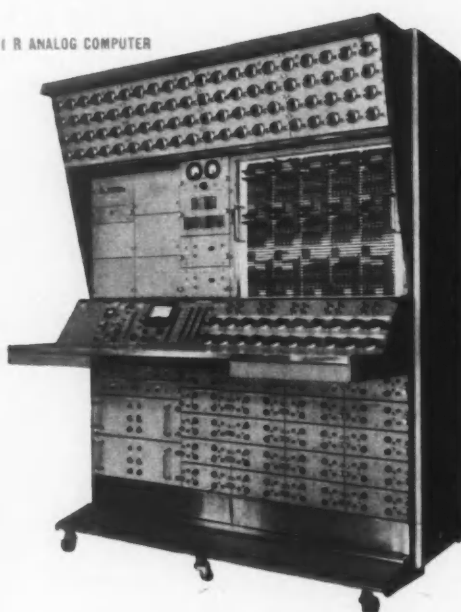
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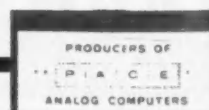
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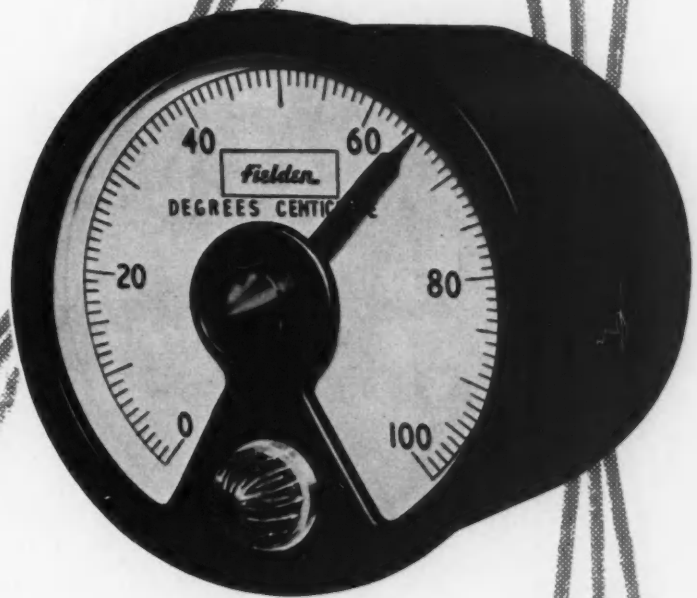
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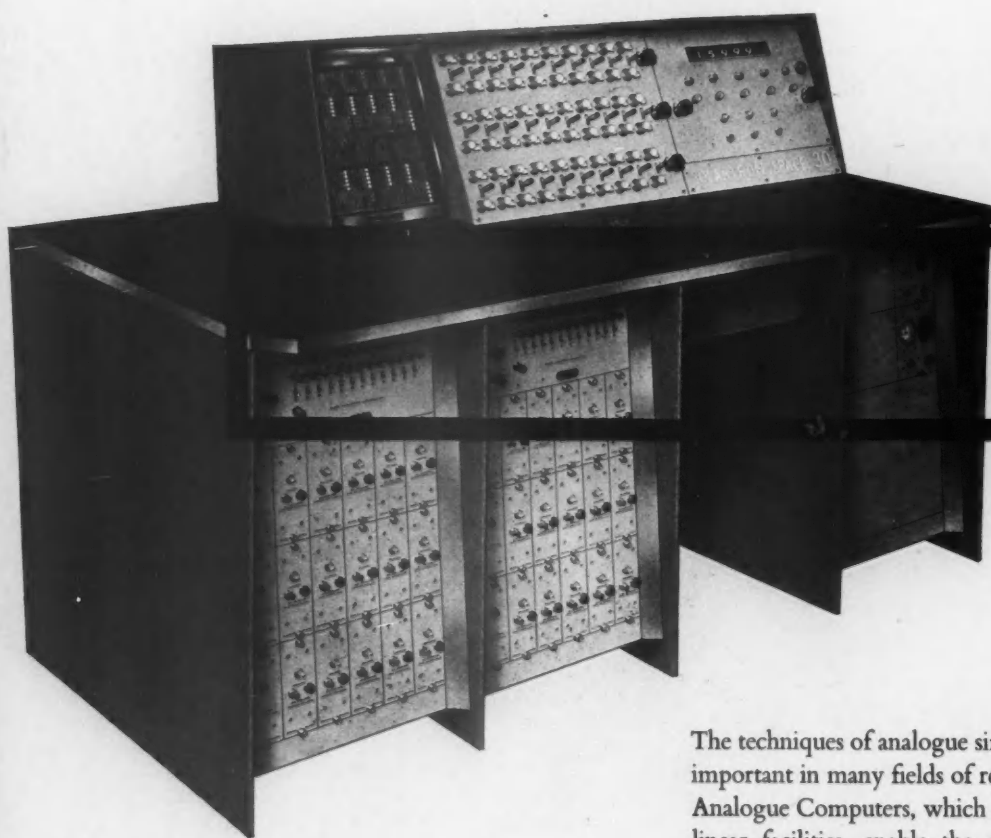
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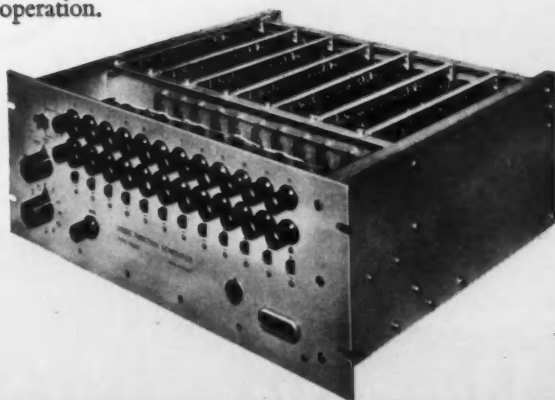
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	15 mV. 1 mV. 500 μ V.	15 mV. 500 μ V.	15 mV. 500 μ V.

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Specification Per Unit

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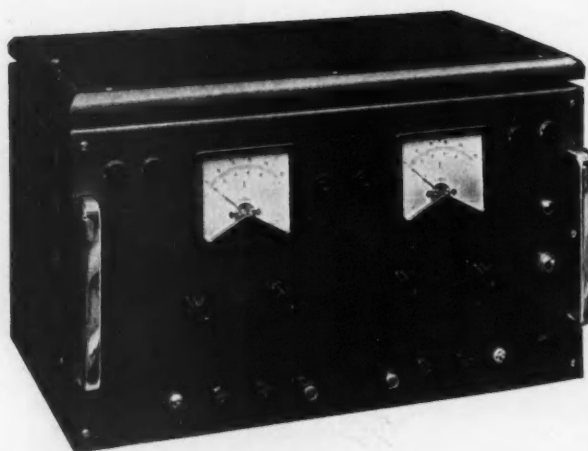
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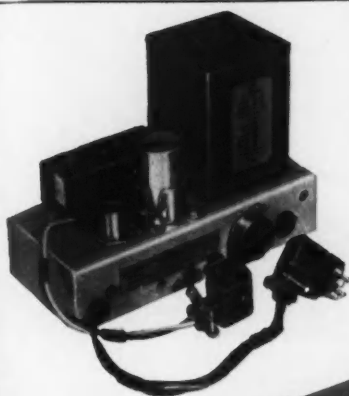
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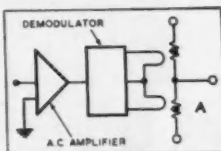
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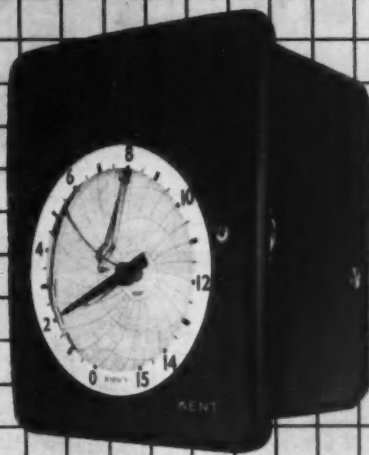
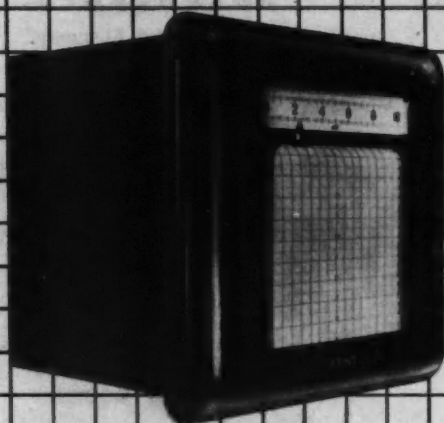


Type 1 Quadrature Suppressor

(Below) Mark 3 electronic recorder (control optional)

(Below) Commander KE recorder-controller

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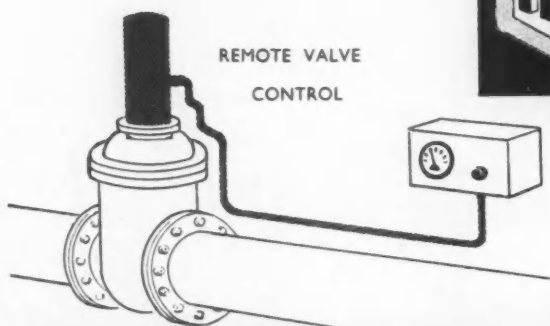
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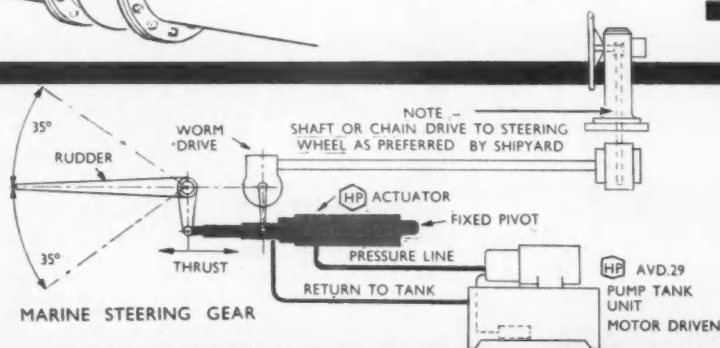


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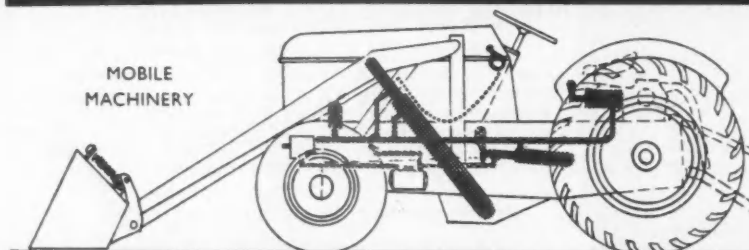
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Our Specialist Team of "Control Engineers" will be pleased to advise on all applications.

HYDRAULICS & PNEUMATICS LIMITED.

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Electronic Sub-Assemblies

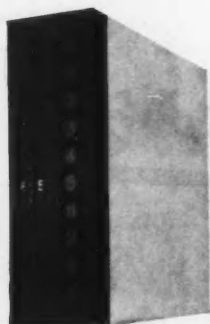
These sub-assemblies provide the shortest route from block diagram through breadboard models and prototypes to complete equipment.

Each sub-assembly is a complete circuit of proven reliability, thus releasing the designer from detailed circuitry, life-testing and proving problems.

In addition to supplying standard units, Mullard Equipment Limited will also design and build sub-assemblies to meet individual specifications.

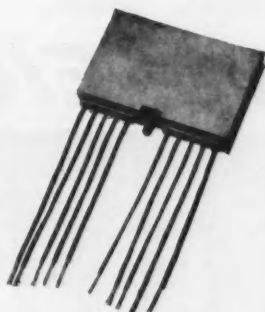
the shortest route
from block diagram
to complete equipment

the first four types available from Mullard Equipment Limited



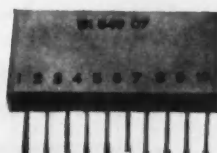
Pre-set Counters for Industrial Control 88930

Up to 10 different switches can be fitted to each of these plug-in units, designed for multiple programmes in industrial control. Counting speeds up to 2,000 per second.



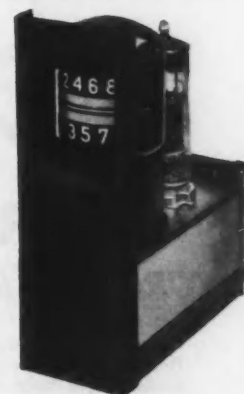
"Norbit" Building Bricks for Industrial Control Systems YL6000

These units incorporate static switching using transistors as the basic switching element for logic design for application in industrial control systems.



"Combi-Element" Building Bricks for Electronic Equipment B1 649

This range of compact complete transistorised circuits, includes flip-flops, emitter followers, gate circuits, multivibrators, inverter amplifiers, etc.



EIT Counter Modules for Instrumentation 88929

Plug-in Decade Counting Units designed for high speed counting, capable of speeds up to 100,000 per second.

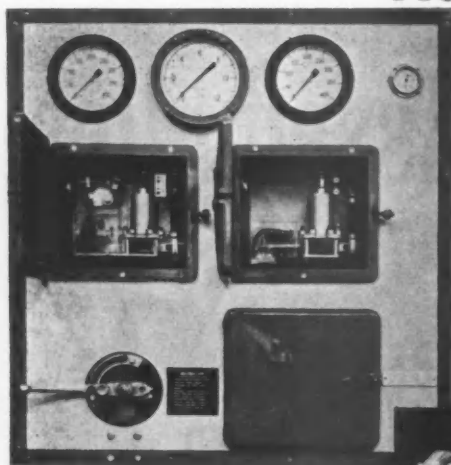
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See Mullard Electronic Equipment
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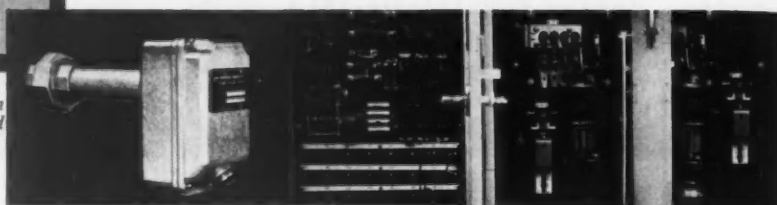
Mullard House, Torrington Place, London, W.C.1
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Automatic Control



A section of the remote control, push-button unit, showing some of the timers, relays and contactors.



A John Thompson Flame Failure unit fitted to the burner.

The control panel housing the pressure controls manual/automatic switch lever, pressure, temperature and draught gauges.

JOHN THOMPSON INSTRUMENT CO LTD • WOLVERHAMPTON



MF 5a

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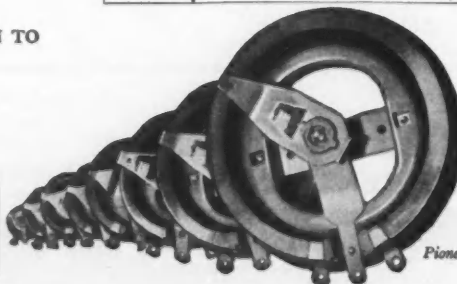
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Onms ± 10%	CURRENT RATINGS							
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1	—	7.07	8.66	10.00	12.50	15.0	17.3	22.3
2	3.54	5.00	6.12	7.07	8.66	10.6	12.2	15.8
3	2.89	4.08	5.00	5.75	7.07	8.66	10.0	12.9
5	2.24	3.16	3.88	4.77	5.48	6.71	7.75	10.0
7.5	1.82	2.56	3.16	3.65	4.47	5.48	6.32	8.17
10	1.58	2.24	2.74	3.16	3.88	4.74	5.48	7.07
15	1.29	1.83	2.24	2.58	3.16	3.87	4.47	5.78
25	1.00	1.41	1.73	2.00	2.45	3.00	3.46	4.47
50	.707	1.00	1.23	1.41	1.73	2.12	2.45	3.16
75	.578	.818	1.00	1.15	1.41	1.73	2.00	2.58
100	.500	.707	.866	1.00	1.23	1.50	1.73	2.23
150	.408	.575	.707	.818	1.00	1.22	1.41	1.82
200	.354	.500	.612	.707	.866	1.06	1.22	1.58
350	.268	.378	.463	.535	.655	.803	.926	1.19
500	.224	.316	.388	.447	.548	.671	.775	1.00
1,000	.158	.224	.274	.316	.388	.474	.548	0.708
1,500	.129	.183	.224	.258	.316	.387	.447	.578
2,500	.100	.141	.173	.200	.245	.300	.346	.448
5,000	—	.100	.123	.141	.173	.213	.245	.315
7,500	—	.081	.100	.115	.141	.173	.200	.258
10,000	—	—	—	.110	.125	—	.173	.224
15,000	—	—	—	—	—	—	—	.183



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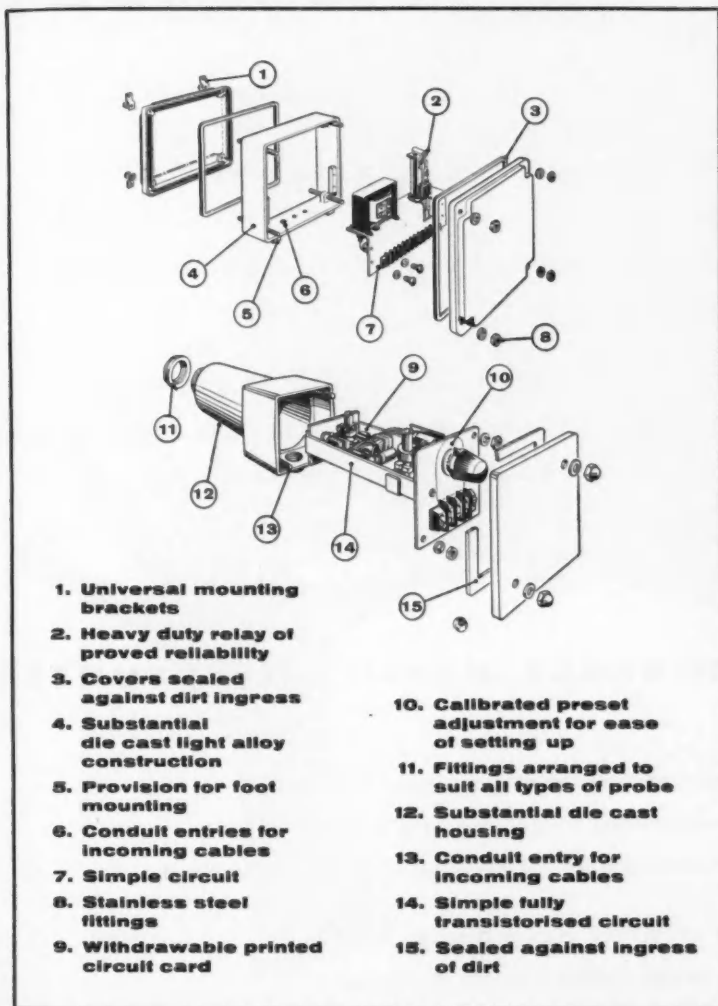
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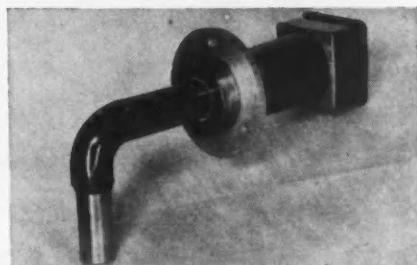
7

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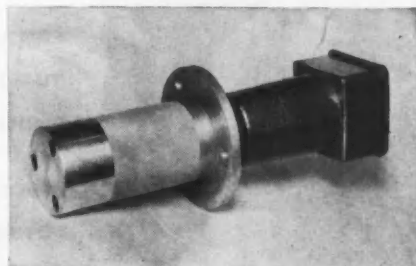


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19

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Over 145 transistors and 21 printed circuit boards are used to achieve an exceptionally sound and compact design, capable of performing efficiently under rigorous conditions. Self-checking facilities are incorporated, and the easy-to-read decade-meter display provides an instant six-figure indication with manual or automatic repetition and an accuracy of ± 1 count.

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FREQUENCY MEASUREMENT from 10 to 1,000,000 c/s

TIME MEASUREMENT from 1 μ sec. to 2777 hours

* **PERIOD MEASUREMENT** 1 or 10 periods of input waveform down to 10 c/s

RANDOM COUNTING totalling over any period

OUTPUT TIMING PULSES from 10^{-1} to 10^6 p.p.s.

INTERNAL STANDARD oven controlled 1 Mc/s crystal

STABILITY ± 1 part in 10^6 at 25°C

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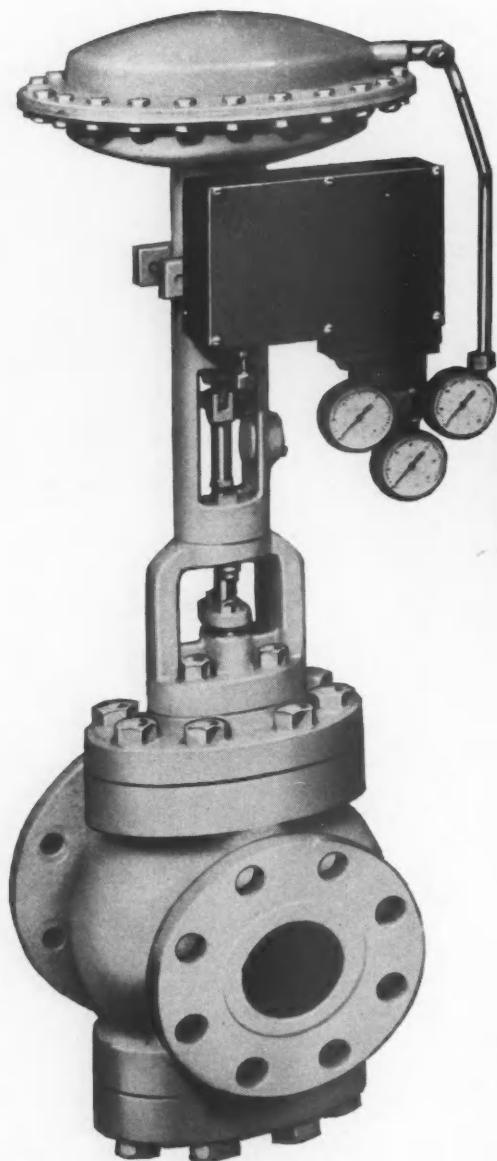
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G32	31.80	15.90	9.52
G33	33.00	22.20	10.00
G3	38.10	26.00	10.15
G34	40.00	26.00	12.00
G4	42.50	28.00	8.60
G4A	42.50	28.00	14.50
G8	47.00	29.00	15.50
G1	50.50	30.00	17.00
G1A	50.50	30.00	13.50

NOM. μ
12
25
50
90
140

CODE	OUTSIDE DIA. MM	INSIDE DIA. MM	THICKNESS MM
G1B	50.50	30.00	10.00
G2	58.00	35.00	17.50
G6	70.00	46.00	20.00
G9	80.00	48.00	29.00
G60	12.70	7.62	4.75
G59	20.32	12.70	6.35
G58	22.86	13.97	7.62
G57	26.92	14.73	11.18
G56A	33.02	19.94	10.67
G56	33.02	19.94	11.18
G55	34.29	23.37	8.89

NOM. μ
12,25
50,90
140

NOM. μ
14
26
60
125
140

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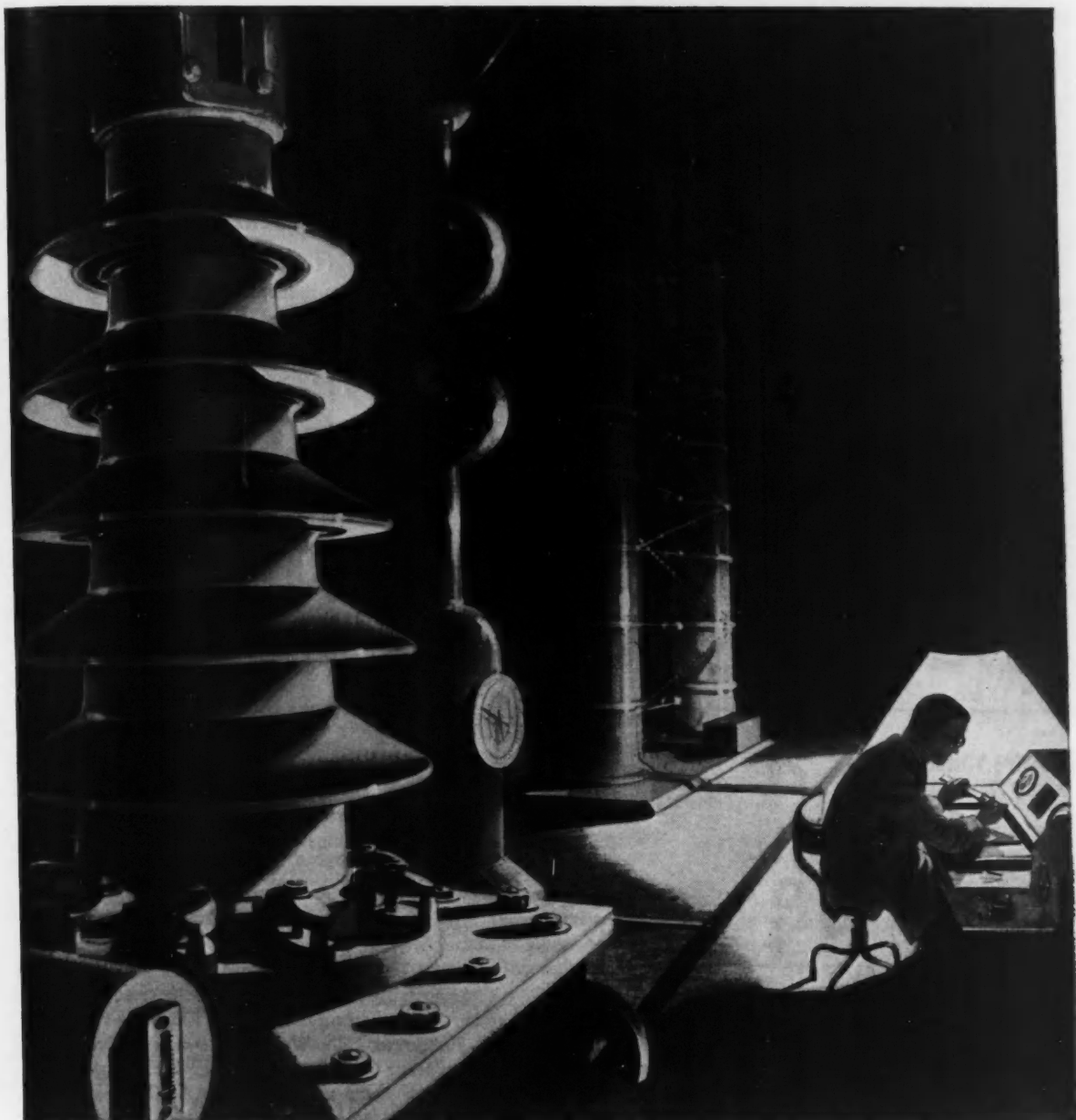
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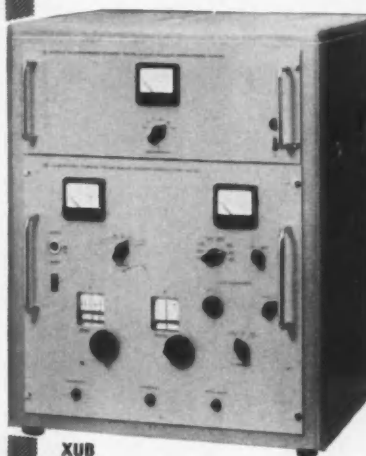
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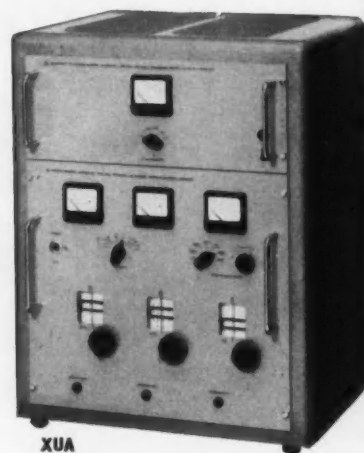
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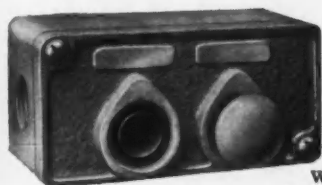
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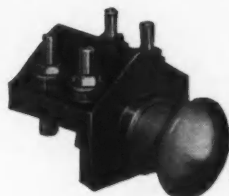


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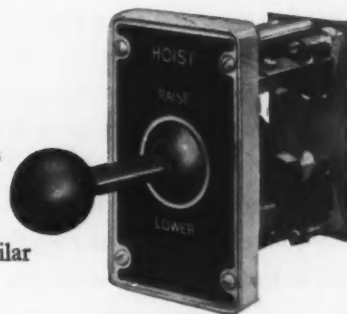
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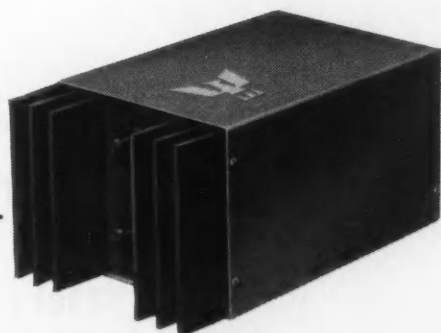
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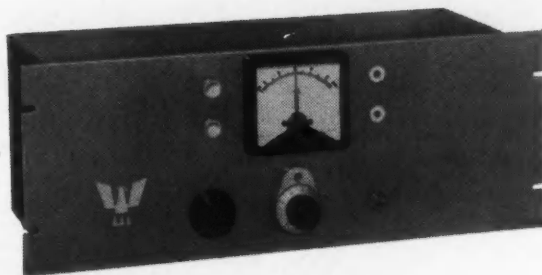
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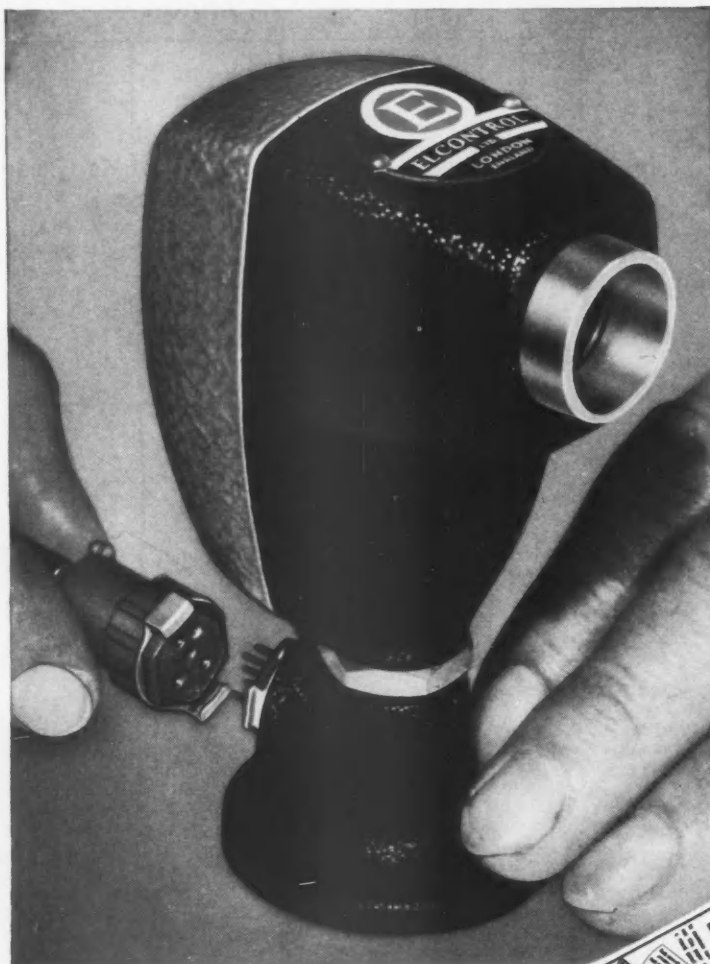
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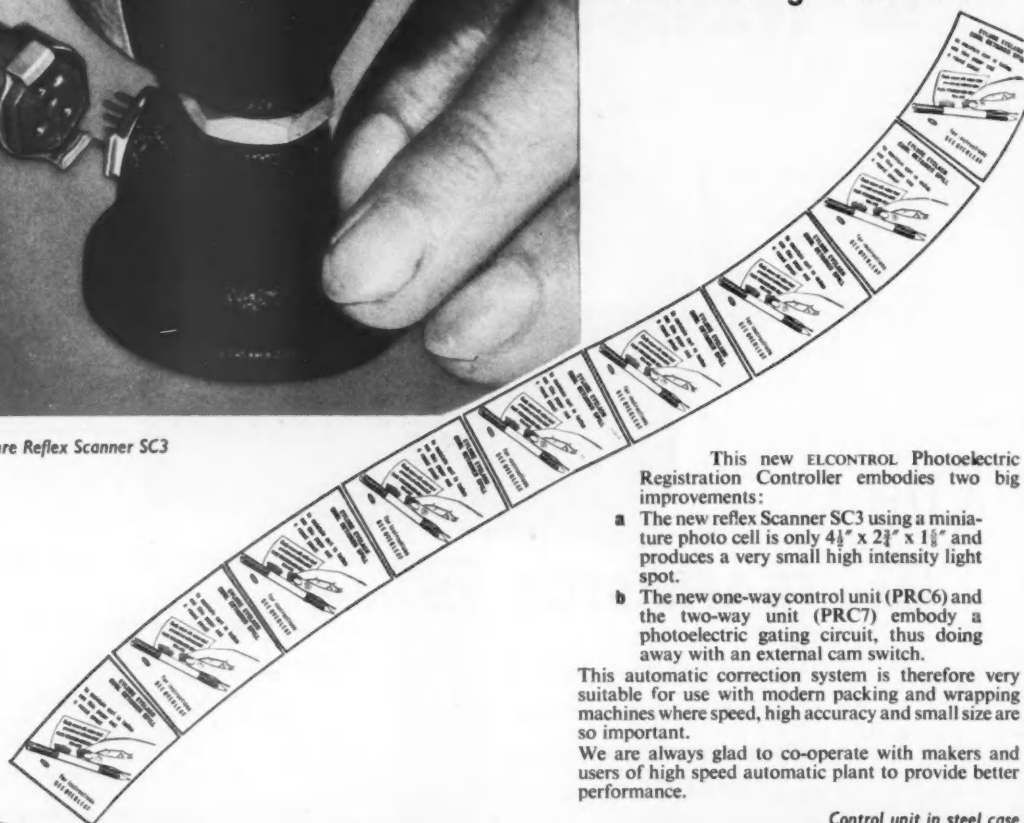




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positive control

for label cutting, wrapping
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Control unit in steel case



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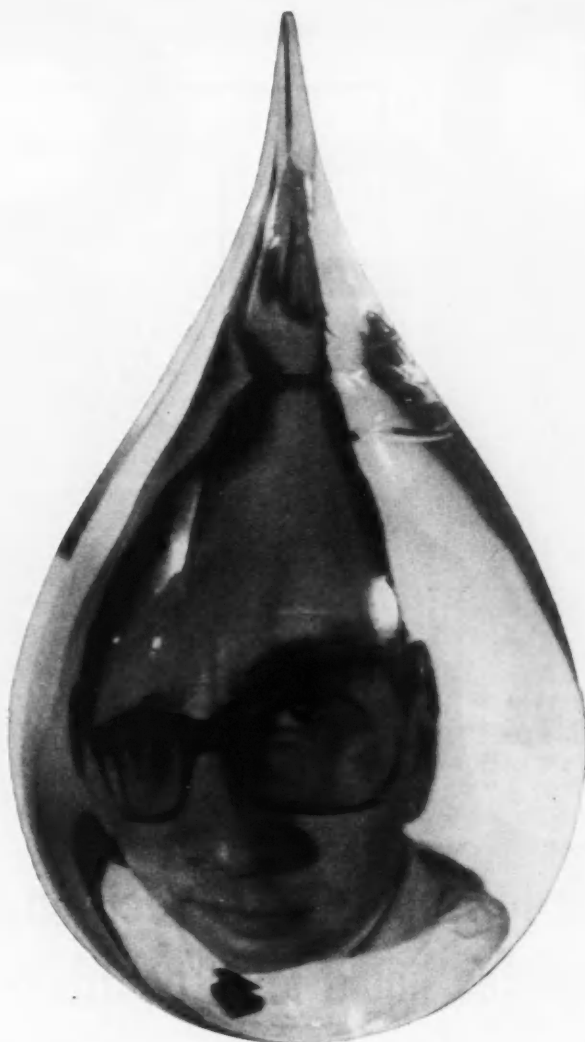
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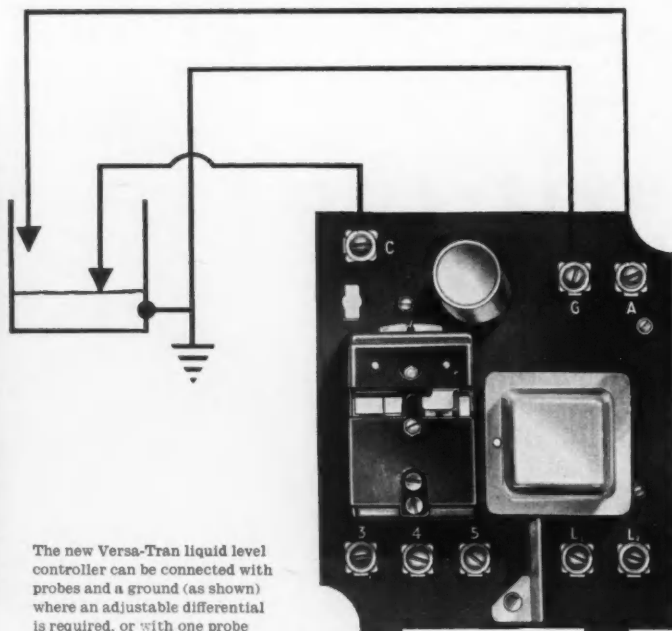
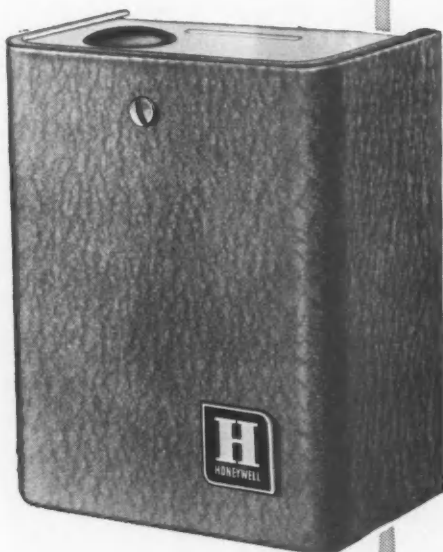
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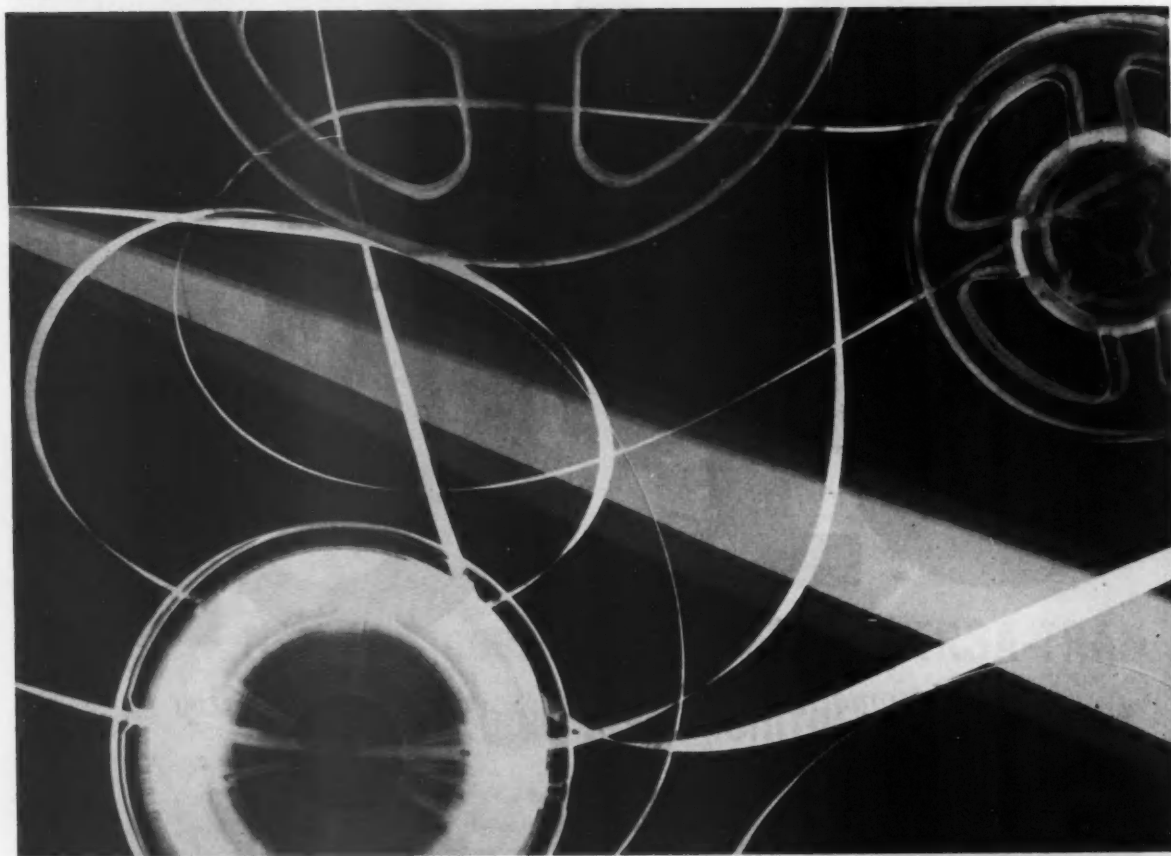
These high-speed Potentiometric Recorders are continuously self-balancing, use electronic power amplification and motor drive. The chart, which is 10" wide, can be traversed in 2 seconds (1 sec. to order). Single or multitrace (2, 4, 8, 16) models are available, the latter with 5 or 15 seconds printing interval. High sensitivity: instrument responds to signals of less than 1 microvolt. Ranges: from 500 microvolts for single-point, 1 millivolt for multi-point models. But much more can be learned from Technical Publication 2042 from *Instrumentation Division, Associated Electrical Industries Limited*.



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Associated Electrical Industries Limited

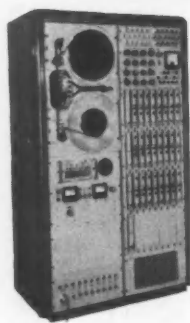
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Light-Sensitive Cells

What are light-sensitive cells? They are devices which can sense and measure changes in the level of light or, in some cases, respond to the quality of light falling on them. There are various types of cell and each has its particular field of use. One of the best known is the photo-electric cell.

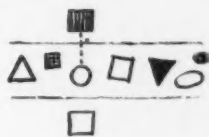
What can light-sensitive cells do? A change in the amount of light falling on the cell can cause a switch, relay or counter to operate. Alternatively, the direct indication of the light intensity can often allow some other factor to be determined and, if required, controlled. They are reliable and require little maintenance. Careful installation, as with all types of equipment, gives a good reward.

How can they be used? These cells have many applications in industry, for controlling processes, for inspection and measurement, for sorting material and for safety purposes:

Counting

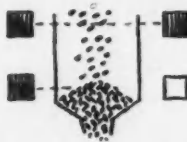
Where objects on a conveyor belt are too soft or light to operate a direct mechanical counting device, where they are too delicate or freshly painted to

sustain physical contact or where the articles vary in size, a light-sensitive cell can be used. This counts the objects by interruption of an appropriately sited beam of light.



Hopper or Tank Level Control

Many forms of feed can be accurately controlled by light cells. One important one is for controlling the input to a hopper of fluid solids such as sand or peas. Here, two horizontal light beams are required: the upper, when interrupted, indicates that the hopper is full and stops the supply; the lower, when it ceases to be interrupted, indicates that the hopper is nearly empty and restarts the flow.



Package Content

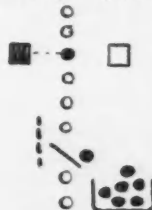
The level of powder in packages can be checked with light cells. The cell is so positioned that when the



powder is up to the required level, the light reflected from the surface of the powder is picked up by the cell and causes the carton to be accepted. If not, it is rejected.

Colour Sorting

The quality of many articles can be gauged by their colour—seeds and nut kernels, for instance. The objects are fed into a tube by means of a vibrator pan and fall into the beams of three equally spaced light cells which scan them from all sides. If the object is acceptable it falls into a chute carrying it to one conveyor; if its colour is bad it is deflected as a reject.



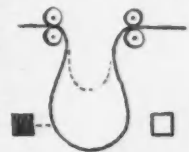
Guillotine Guard

Light cells for guarding a guillotine or power press should be used only as a supplement to a mechanical guard or where the latter is impracticable. The interruption of a curtain of light by a hand stops the machine instantaneously.



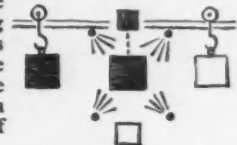
Press Feeding

Where the rate of feed of strip metal must be suited to a varying speed of acceptance by a press, a loop of the strip is allowed to sag between the feed and the press. When the loop reaches a predetermined depth a light beam is interrupted and the slack is taken up.



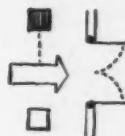
Processing Objects on the Move

Many articles are processed while on a conveyor line. For instance, where articles are to be sprayed while on the conveyor, the paint saved by stopping the gun between articles will make the device worthwhile. The same principle applies in a bakery to the spraying of baking tins with fat.



Automatic Door Opening and Closing

Doors can be caused to open or close by the interruption of a beam of light. This has its uses in such cases as control of doors on a heating oven or for the passage of vehicles in a factory. This is effected by a light beam on the side from which the approach is made (in many cases, both). When the approach beam is interrupted it opens the door which closes again after a given time interval.



For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association.

An excellent series of reference books are available (8/6 or 9/- post free) on electricity and productivity—"Higher Productivity" is an example. E.D.A. also have available on free loan a series of films on the industrial uses of electricity. Ask for a catalogue.

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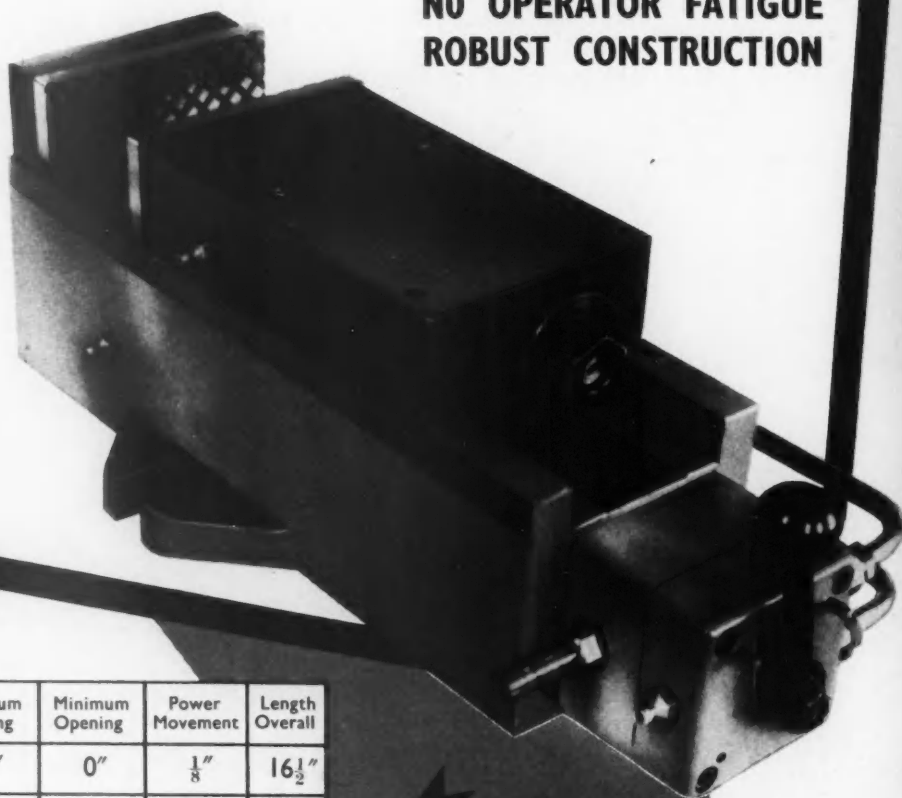
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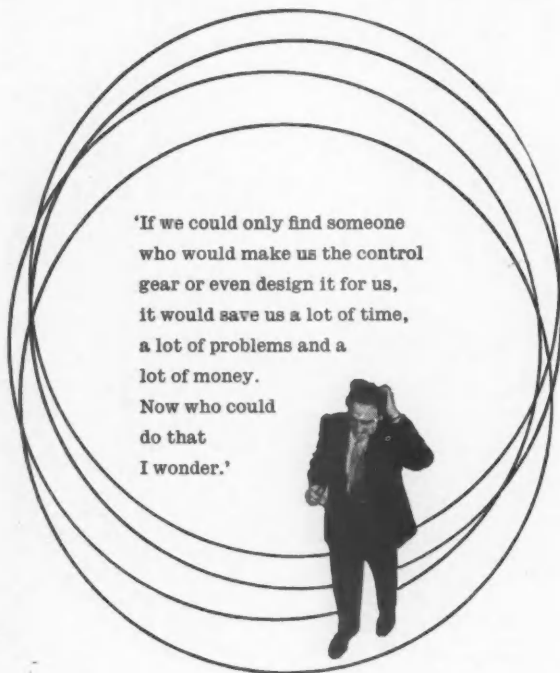
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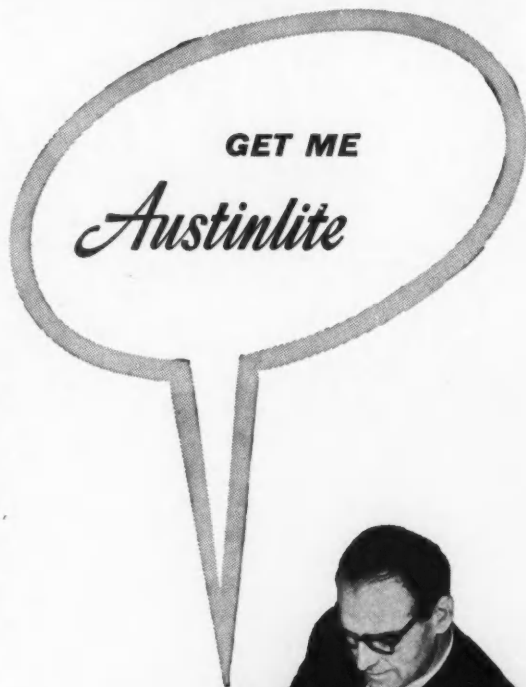
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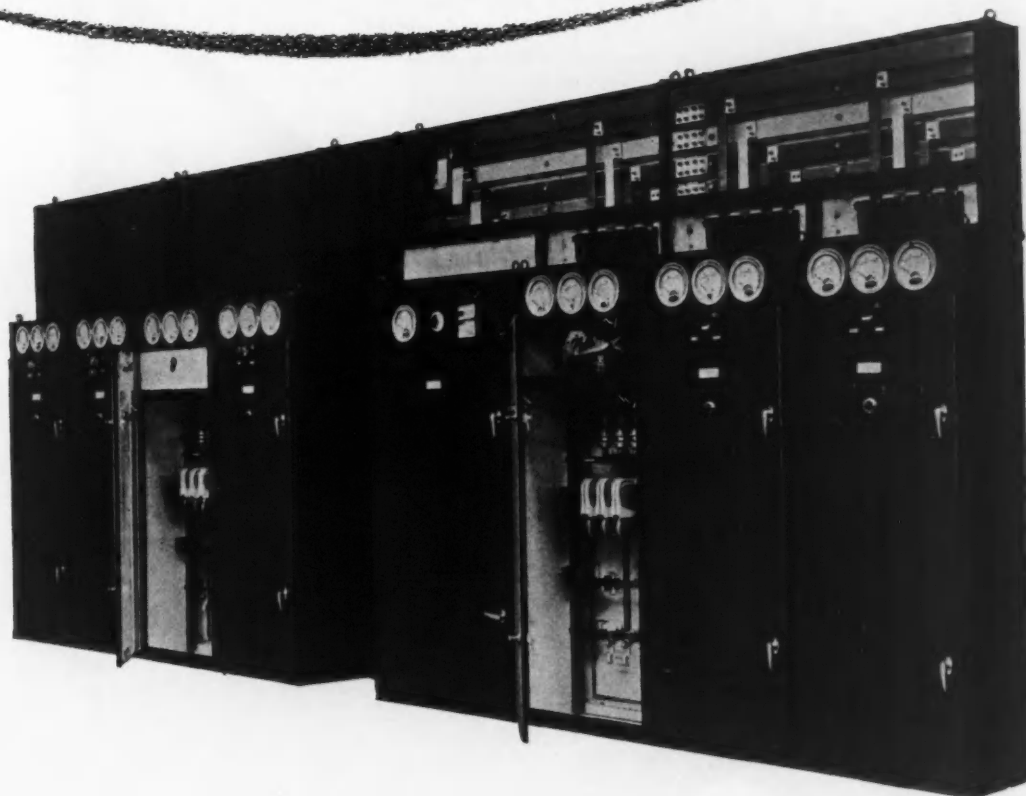
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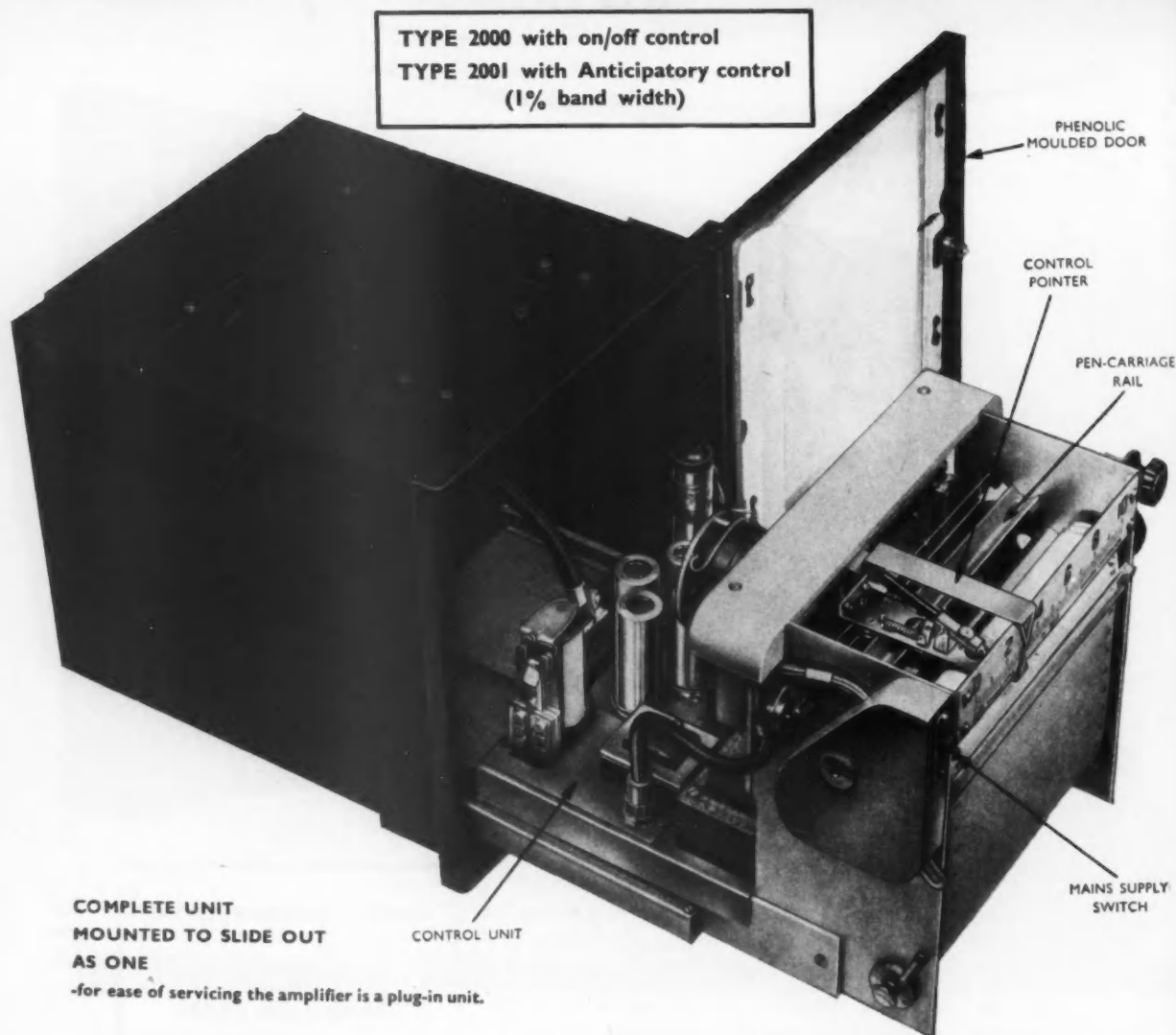
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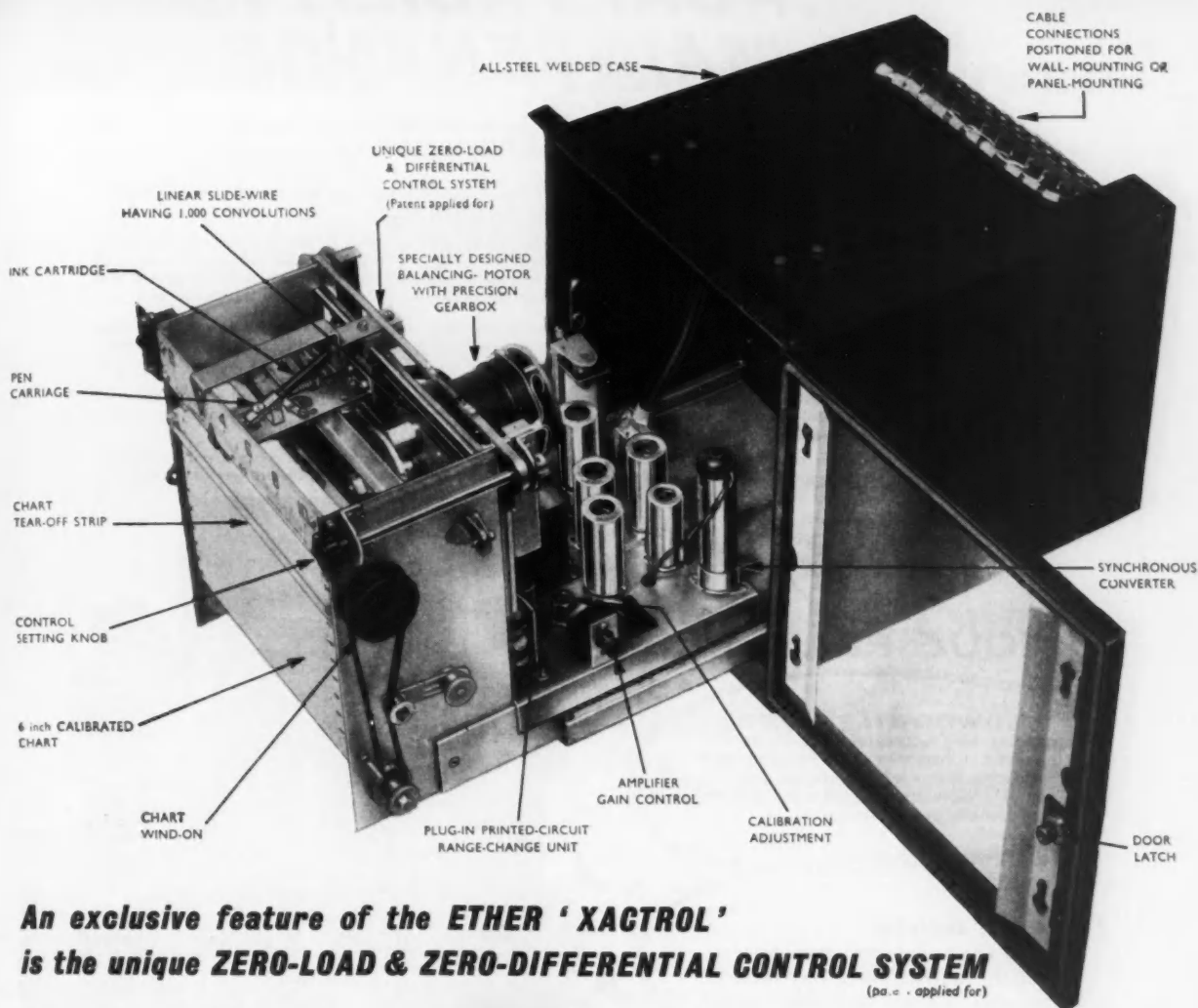
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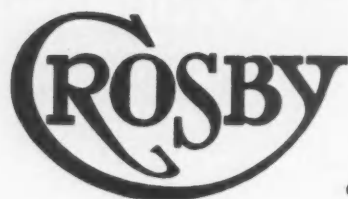
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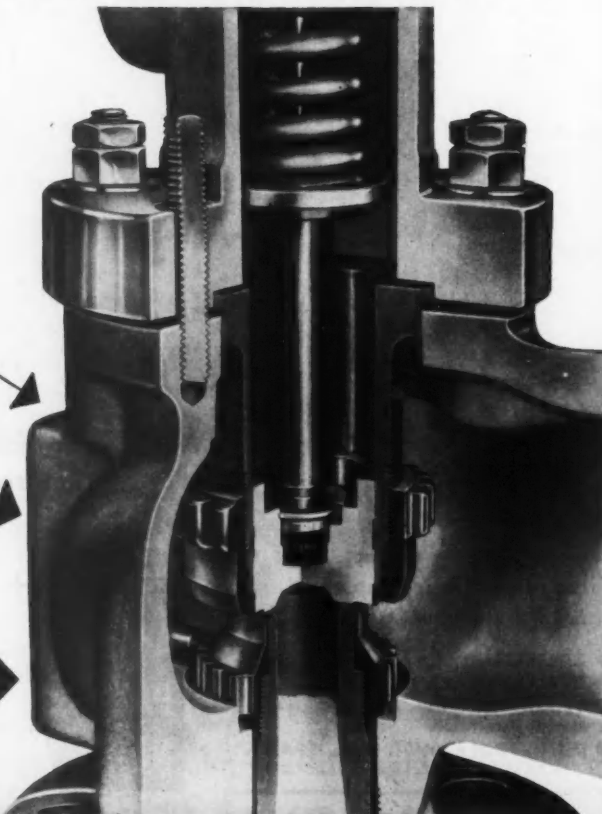
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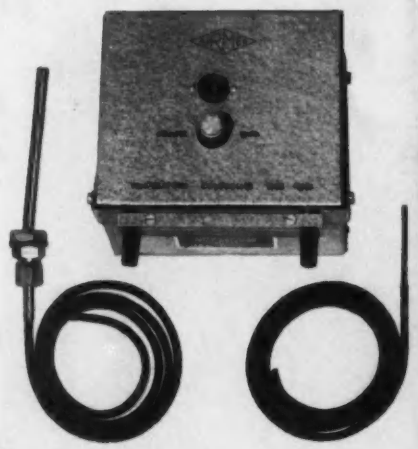
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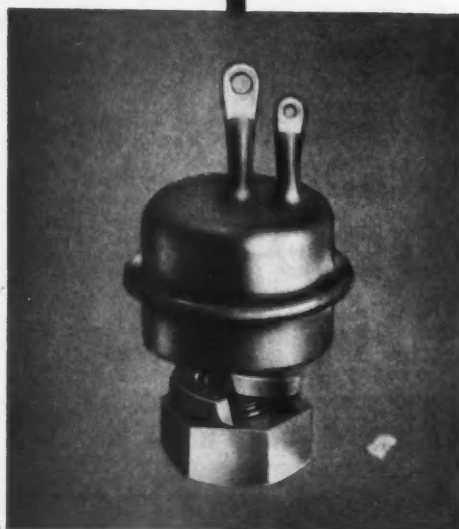
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CX10/100	100	10	0.1	CX5/100	100	5	0.1
CX10/150	150	10	0.1	CX5/150	150	5	0.1
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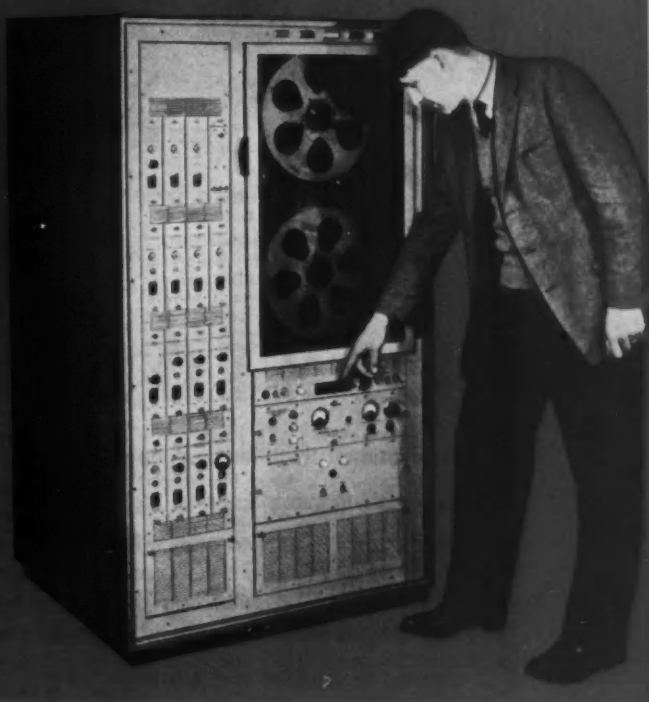
Pressures
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Flow Rates
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Etc.

PUT IT ON

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Magnetic tape will record more data, faster, more accurately than any other medium.

The Solartron LW 980 Magnetic Tape Recorder-Reproducer System has been introduced for evaluating behaviour of complex dynamic systems—either industrial or military—by precise recording of multiple input signals, for subsequent reproduction and analysis.



- * Frequency range DC to 100 Kc/s.
- * Multichannel input and output facilities.
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- * Input: 0.5 to 25 V, rms; Output: Nominal 2 V rms.
- * Environmental Range 40° to 95° F at 100% Humidity, Corrosion-Resistant throughout.

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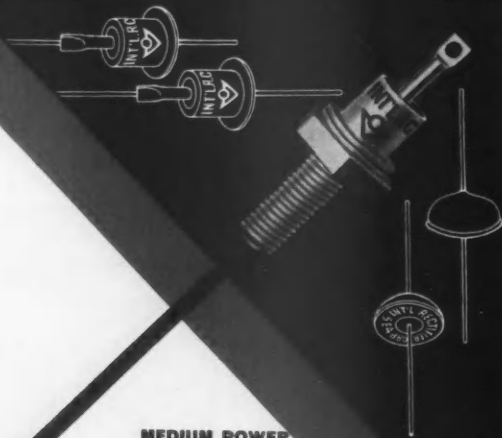
Tel: Farnborough (Hants.) 3000.

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51

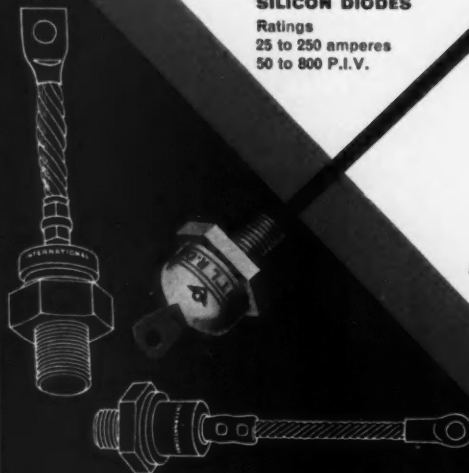


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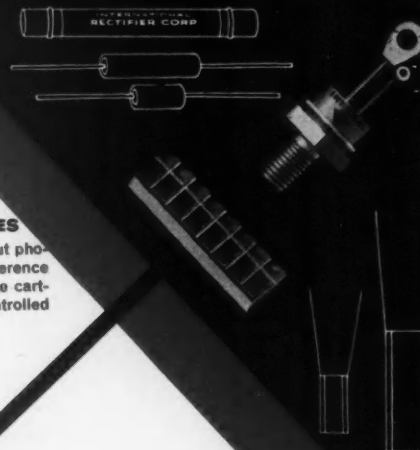
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2 Mc/s

VS.10.H

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This new beam switching tube is the second in a range of Trochotrons under development by Ericsson Tube Division. Its outstandingly high current output offers a ready means of directly operating any of the series of Digitron® register tubes or similar devices including electromechanical registers. Its high speed will be of particular interest to engineers engaged in the design of nucleonic equipment, digital computers and other switching applications. The circuitry associated with the Trochotron being simple, gives added reliability and consequently saves on component costs. The overall dimensions of the VS.10.H are the same as the earlier VS.10.G.



BRIEF SPECIFICATION

Max. Target Voltage	300V	Min. Input Pulse Duration	0.25 μ s
Nom. Spade Voltage	140V	Max. Counting Speed	2 Mc/s
Max. Target Current	18mA	Heater 6.3V	0.5A

N.B. The VS.10.H specification embraces that of the VS.10.G

The whole range of Trochotrons will be colour coded for ease of identification.
VS.10.G—Red VS.10.H—Yellow

For further details write to: The Technical Services Dept.

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TUBE DIVISION

BEESTON • NOTTINGHAM

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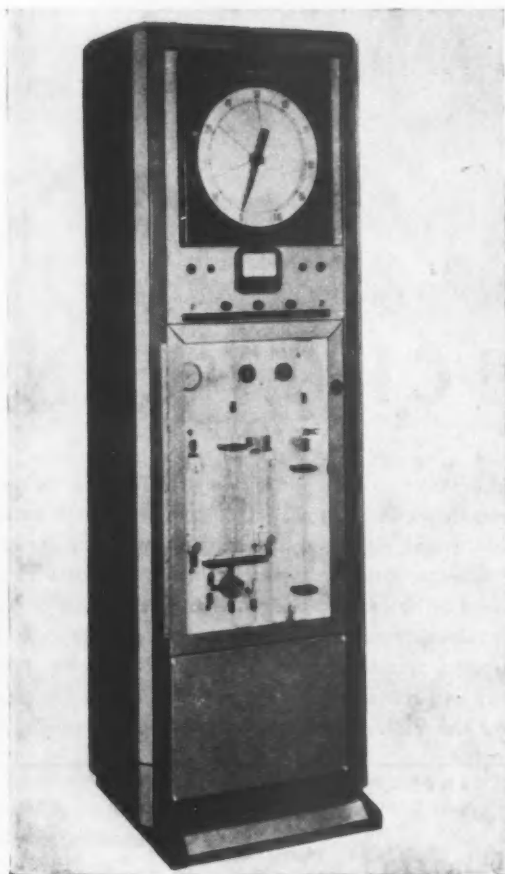
CONTROL April 1960

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53



OXYGEN RECORDER



The Oxygen Recorder has been manufactured for a user to continuously record traces of oxygen in his product in the range 0-100 ppm.

The determination, which involves a single regenerating reagent, is carried out colorimetrically. The instrument employs a stabilised photo multiplier coupled to a simple cathode follower unit which, in turn, feeds a potentiometer recorder. Facilities are provided for standardising the equipment.

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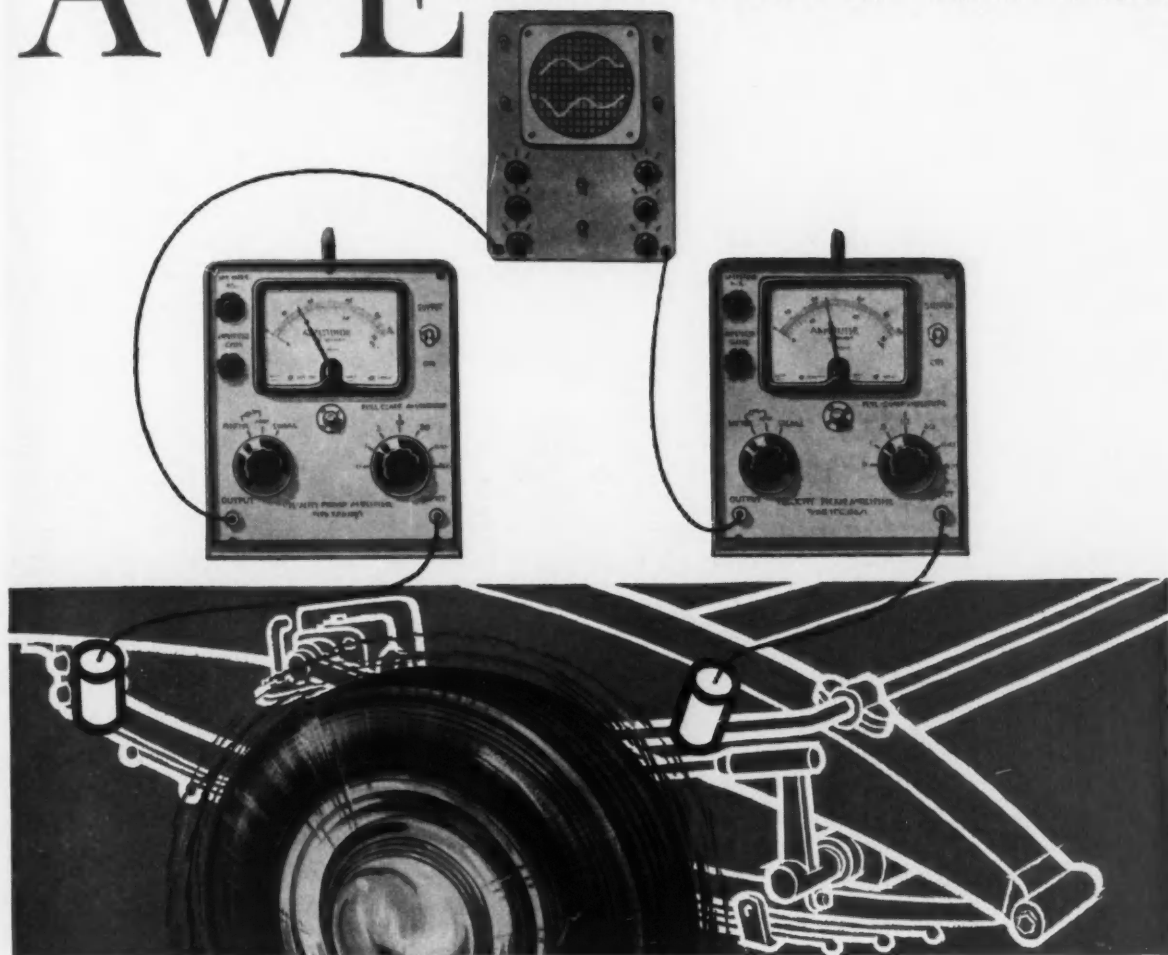
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This unit is primarily designed to convert the output of a seismic or non-seismic velocity pick-up into an easily read meter presentation. The meter is provided with two scales having full scale calibrations of 100 and 30 divisions, and a scale length of 3.25". Full scale deflections are obtained for amplitudes of from 0.3 to 300 thousandths of an inch, in the frequency range 1.5—1500 c.p.s. An important feature of the equipment is that calibration facilities are included in the specification, enabling long and short term

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- 1 Direct Reading
- 2 Built-in Calibration Facilities
- 3 Clear Open Scale
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- 5 Robust and Reliable

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are only a few of the features that put the S31 far ahead of any other portable scope.

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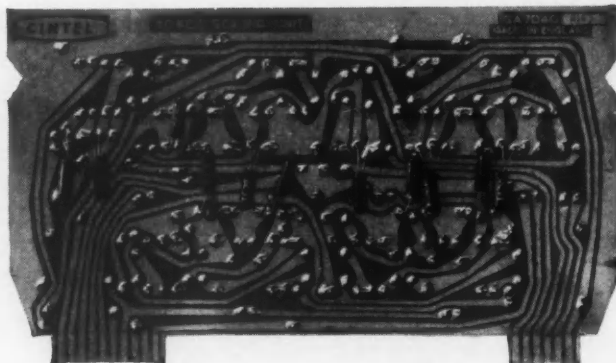
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1Mc/s Read-out Scaler

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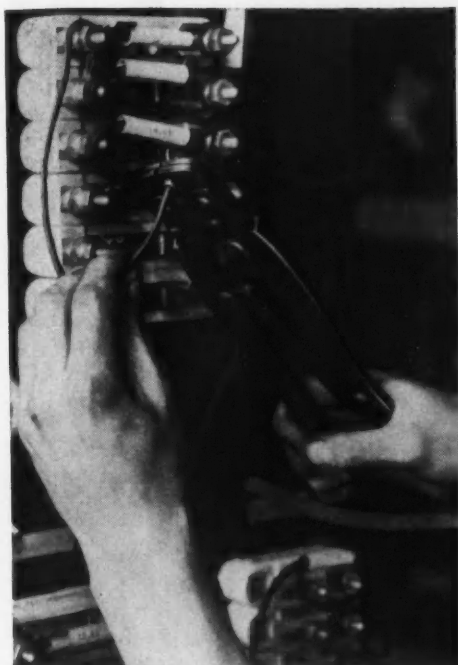
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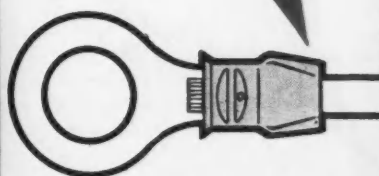
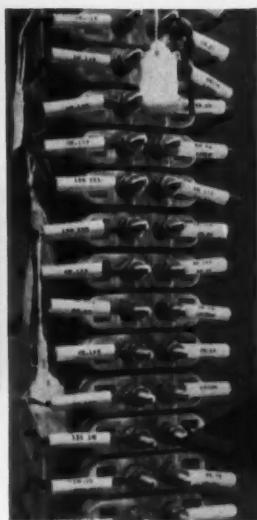
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Close-up of Heavy Duty Plasti-bond Terminals being applied during erection of the new Signal Installation at St. Pancras.



Close-up of fitted Terminal Block.



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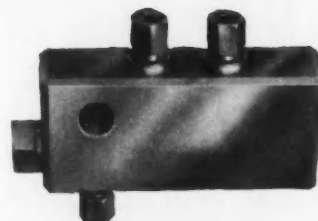
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HML MECHANICAL TRANQUILLISERS
CALM DOWN YOUR SYSTEM

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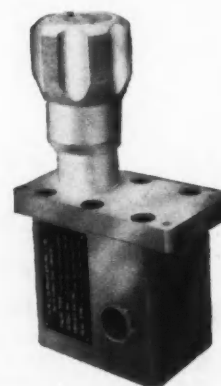
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The only pressure reducing valve on the market today that will maintain set reduced pressure under varying pressure and flow conditions. Pressure range 0-5000 p.s.i. Flow range 0-10 g.p.m.



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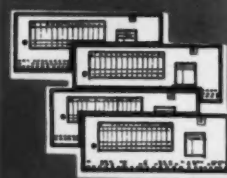
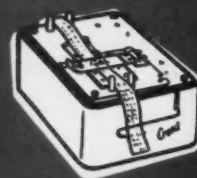
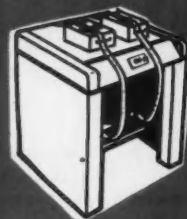
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Record computer output—at speeds up to 300 characters per second; create input data tapes (with or without simultaneous page print-out); provide automatic "common language" punched tapes of routine operations of cash registers, accounting machines, typewriters, etc.

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For continuous automatic telegraphic transmission of punched tape data at full circuit capability; for input of data to computers and other tape-controlled equipment.

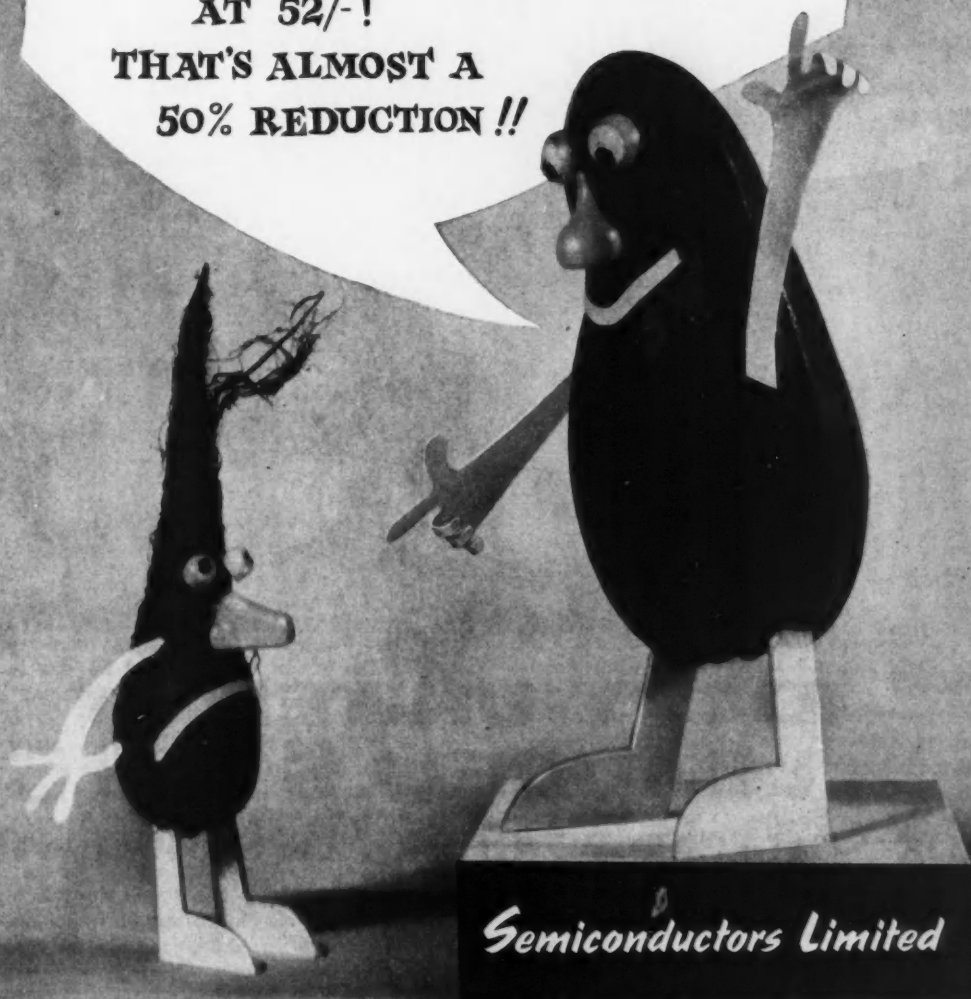
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Facilities for verifying, comparing, correcting, duplicating, combining and winding tapes—automatically, at high-speed.

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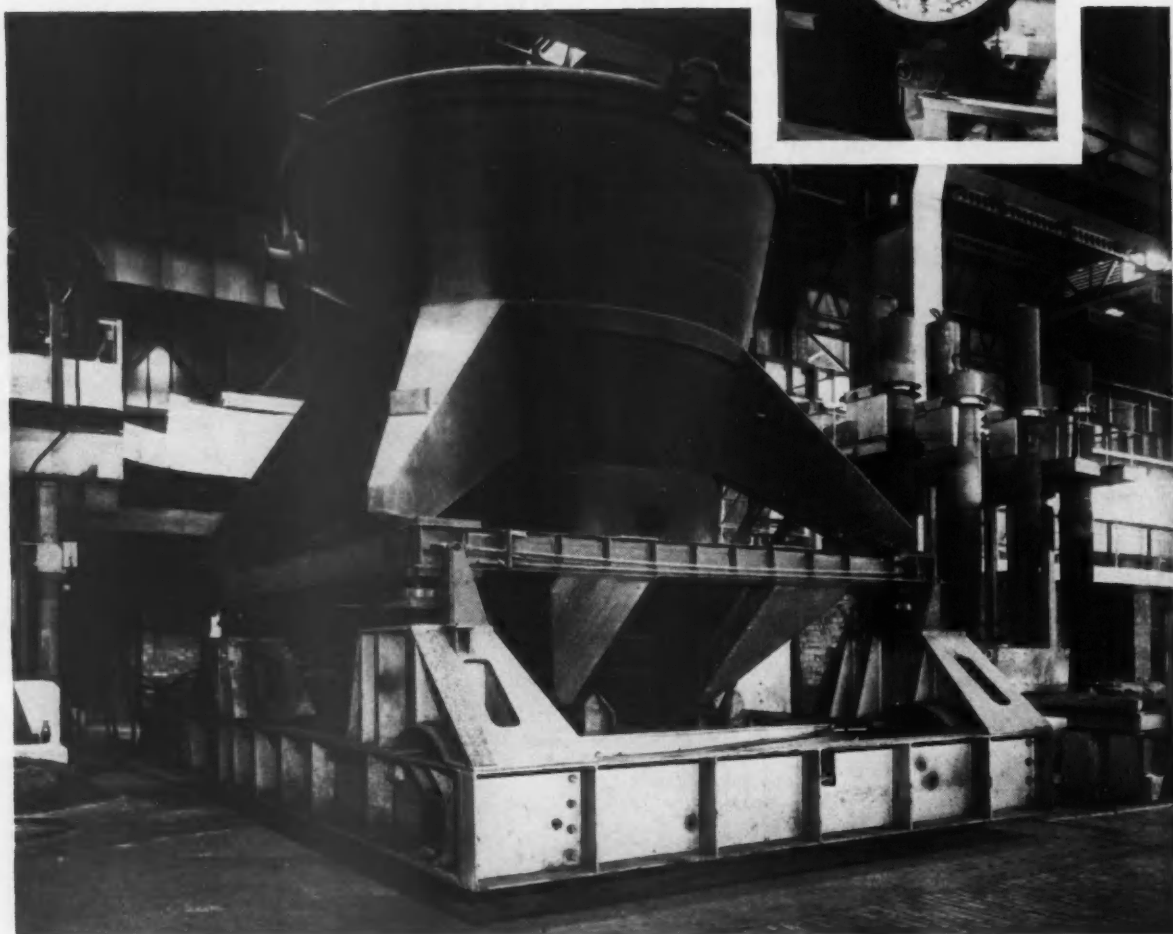
Alpha-numeric punching of data along edges of unit-record cards and tickets with simultaneous page print-out of coded data; automatic high-speed conversion of edge card data to punched tape for telegraphic transmission and/or further machine processing.

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DON'T YOU KNOW THAT THE
2N 502 WILL GIVE A POWER
GAIN OF 10dbS AT 200M/cs
AND IS NOW AVAILABLE HERE
AT 52/-!
THAT'S ALMOST A
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DAVY-UNITED LOADCELLS

FOR SCALECAR WEIGHING AT SAMUEL FOX



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DAVY AND UNITED INSTRUMENTS LIMITED, DARNALL WORKS, SHEFFIELD 9

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We are living in an age where things are moving faster. Today, there is a greatly increased tempo in technology, a growing complexity of design and a multiplication of parts.

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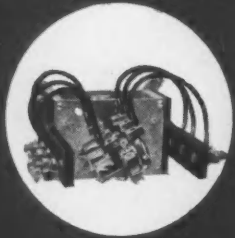
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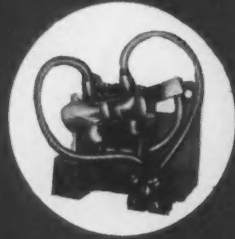
LATEST DESIGN MINIATURE PLUG-IN RELAY



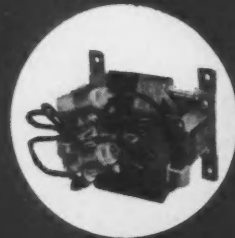
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Available in 10A, 15A, 20A, 25A and 30A ratings. Suitable for use in motor circuits, lighting, heating, etc. Features a built-in thermal protection device.



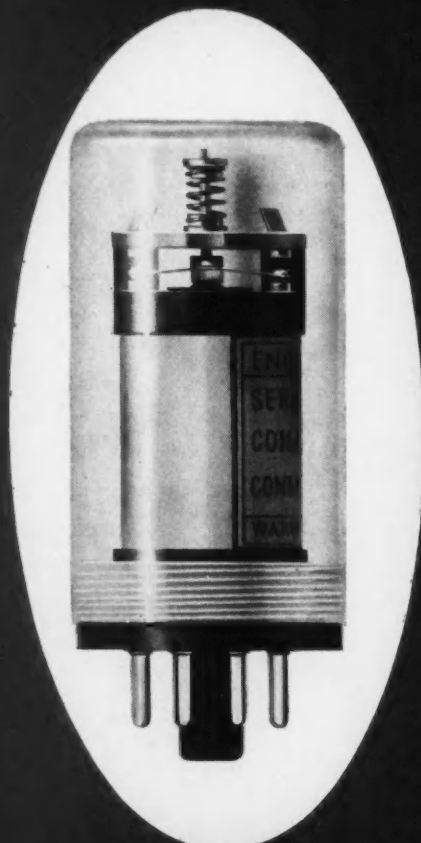
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Available in 10A, 15A, 20A, 25A and 30A ratings. Suitable for use in motor circuits, lighting, heating, etc. Features a built-in thermal protection device.



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Available in 10A, 15A, 20A, 25A and 30A ratings. Suitable for use in motor circuits, lighting, heating, etc. Features a built-in thermal protection device.



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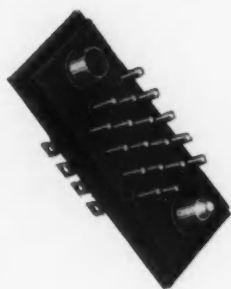
MARK OF TECHNICAL PROGRESS



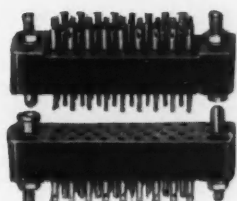
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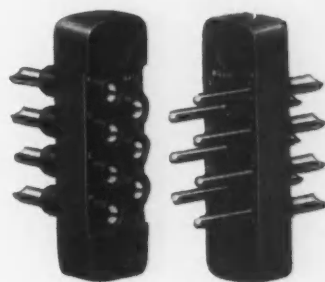
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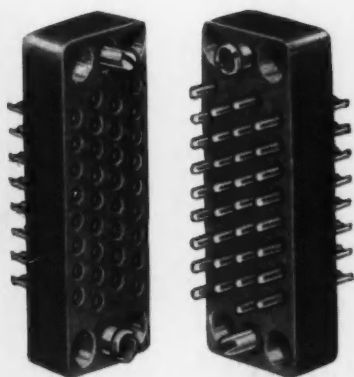
**HERMETIC
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**SUB-MINIATURE
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**POWER
SERIES**

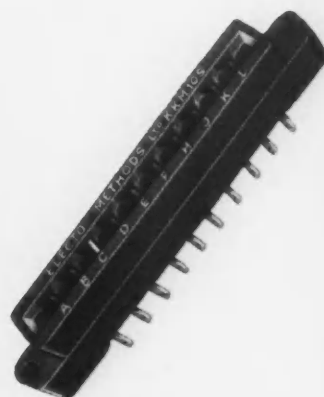


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Electrical Connectors

- * *Precision Mouldings*
- * *Gold-plated Contacts*



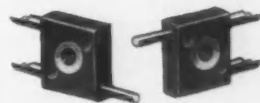
**PRINTED CIRCUIT
SERIES**



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**SUB-MINIATURE ROUND
SERIES**

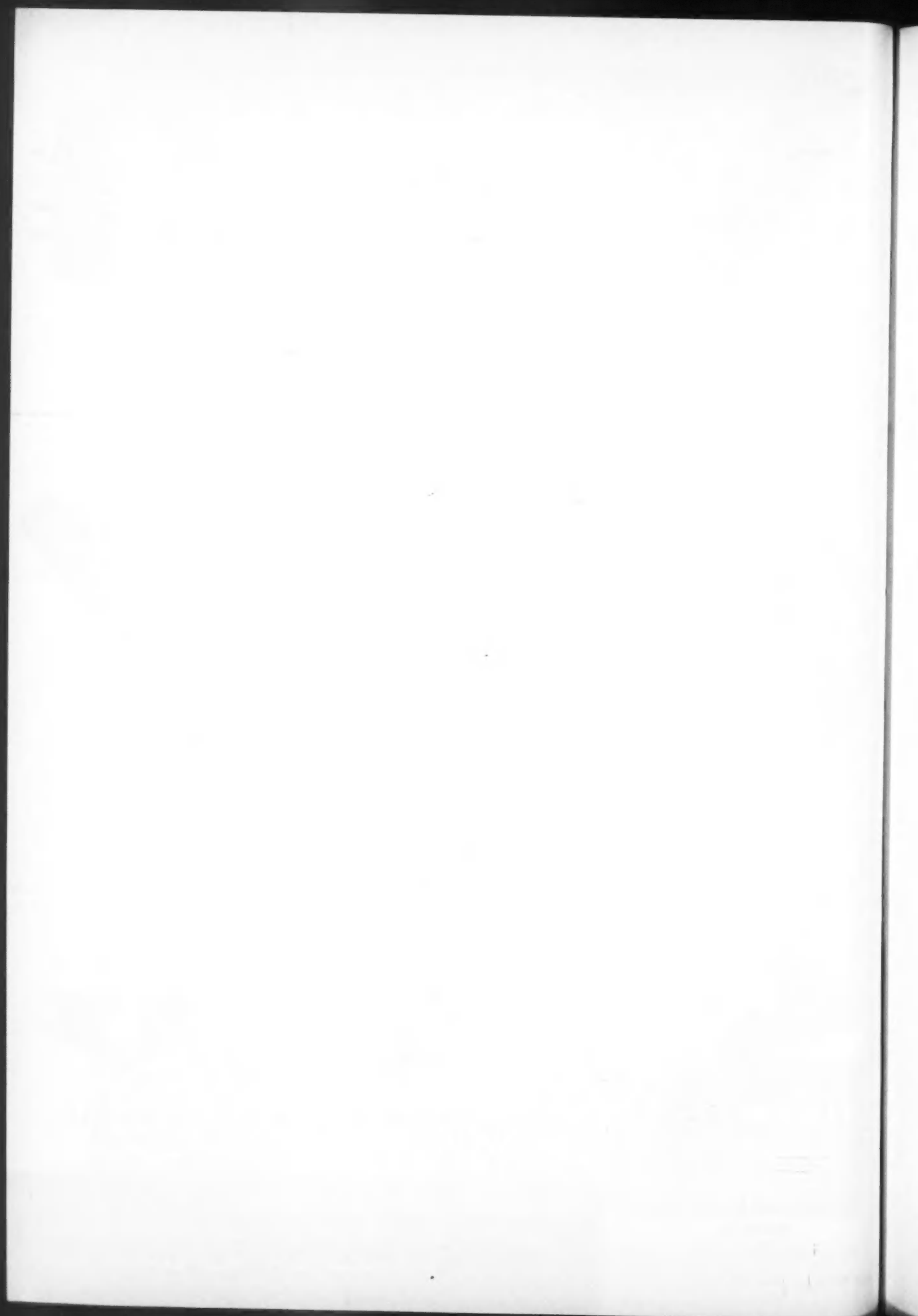


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OF AMERICA

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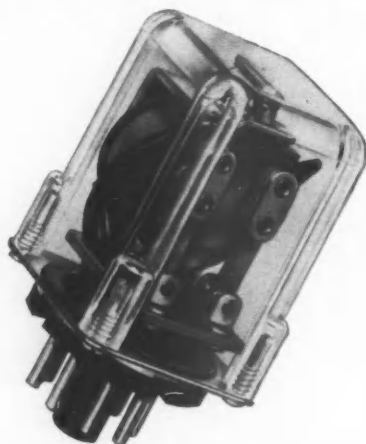
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New...THORN PLUG-IN RELAYS

Thorn Pygmy Power Relay



New interchangeable relay designed for use in remotely controlled automation units. Has double pole changeover contacts. Dust proof—transparent plastic cover. Plugs into any standard International octal valve base.

Weight Only 4½ ozs . . . projection only 2" above base.

Mechanical life over 10,000,000 operations.

Switching current: 5 amps maximum at 250 volts A.C.

Maximum surge current: 10 amps.

Operate time: 8 milliseconds approx.

Release time: 6 milliseconds approx.

Overall dimensions: 1½" square by 2⅝"

Coil voltage: 240 volts standard; also available for 6, 12, 24, 48, 60, 110 volts

Thorn T9 Micro-Switch Relay

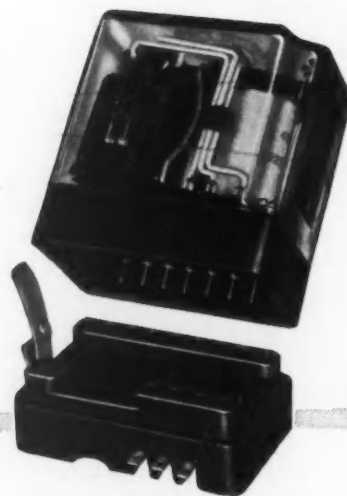
A plug-in relay, particularly suitable for switching P.A. equipment, the snap action contacts minimising interference with pick-up loads.

Operating coil wound for any specified voltage up to 240 volts A.C. or 150 volts D.C. May be tropicalised.

Up to three micro-switch pattern contacts mounted on standard coil frame.

Versions available with up to 11 solder tags or 10 screw terminals.

Contacts:	3 changeover.
Mechanical Life:	Over 10,000,000 operations.
C/O Time:	C.O. period less than 2 milliseconds.
Max. Switch:	10 amps/240 volts A.C. non inductive load.
Capacity:	0.2 amps/240 volts D.C. " " "
	0.5 amps/110 volts D.C. " " "
	1.0 amps/50 volts D.C. " " "
	5 amps/24 volts D.C. " " "
Max. Operate Speed:	20 cycles/sec.
Switching:	Up to 0.1 amp. approx. 20 cycles/sec.
Frequency:	" " 1 " " 5 " "
	" " 5 " " 1 " "
	" " 10 " " 0.1 " "
	(referred to A.C. non-inductive load).

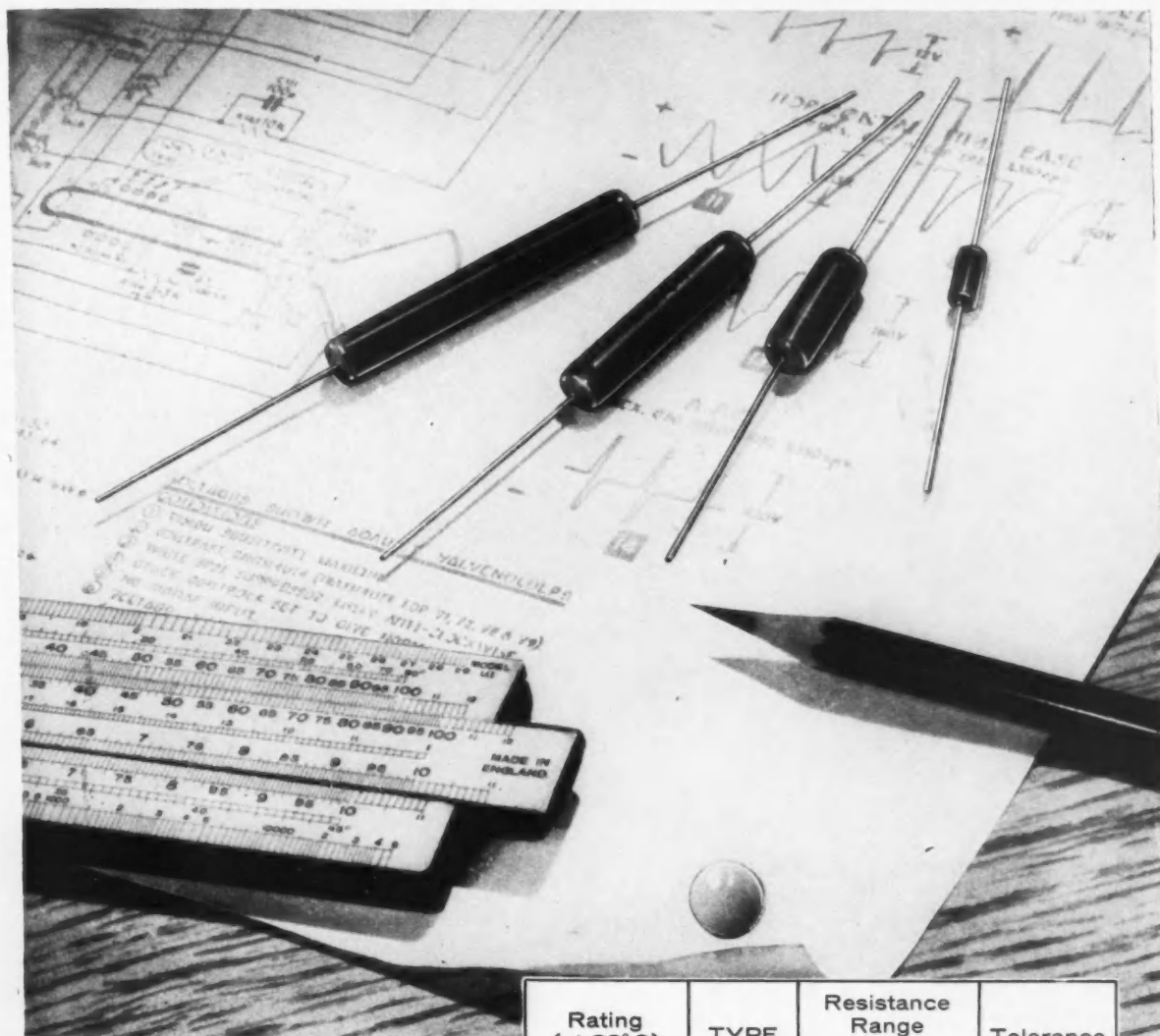


Thorn

COMPONENT AND CONNECTOR DIVISION

Thorn Electrical Industries Limited, Great Cambridge Road, Enfield, Middlesex. Tel | hone: ENField 5353

PAINTON Miniature Vitreous Wirewound Resistors



Rating (at 20°C) Watts	TYPE	Resistance Range ohms		Tolerance
		Min	Max	
4	MV1A	1 10	9.9 6,800	10% 5%
7	301A	2	68,000	5%
10	302A	4	140,000	5%
5	306A	1	33,000	5%

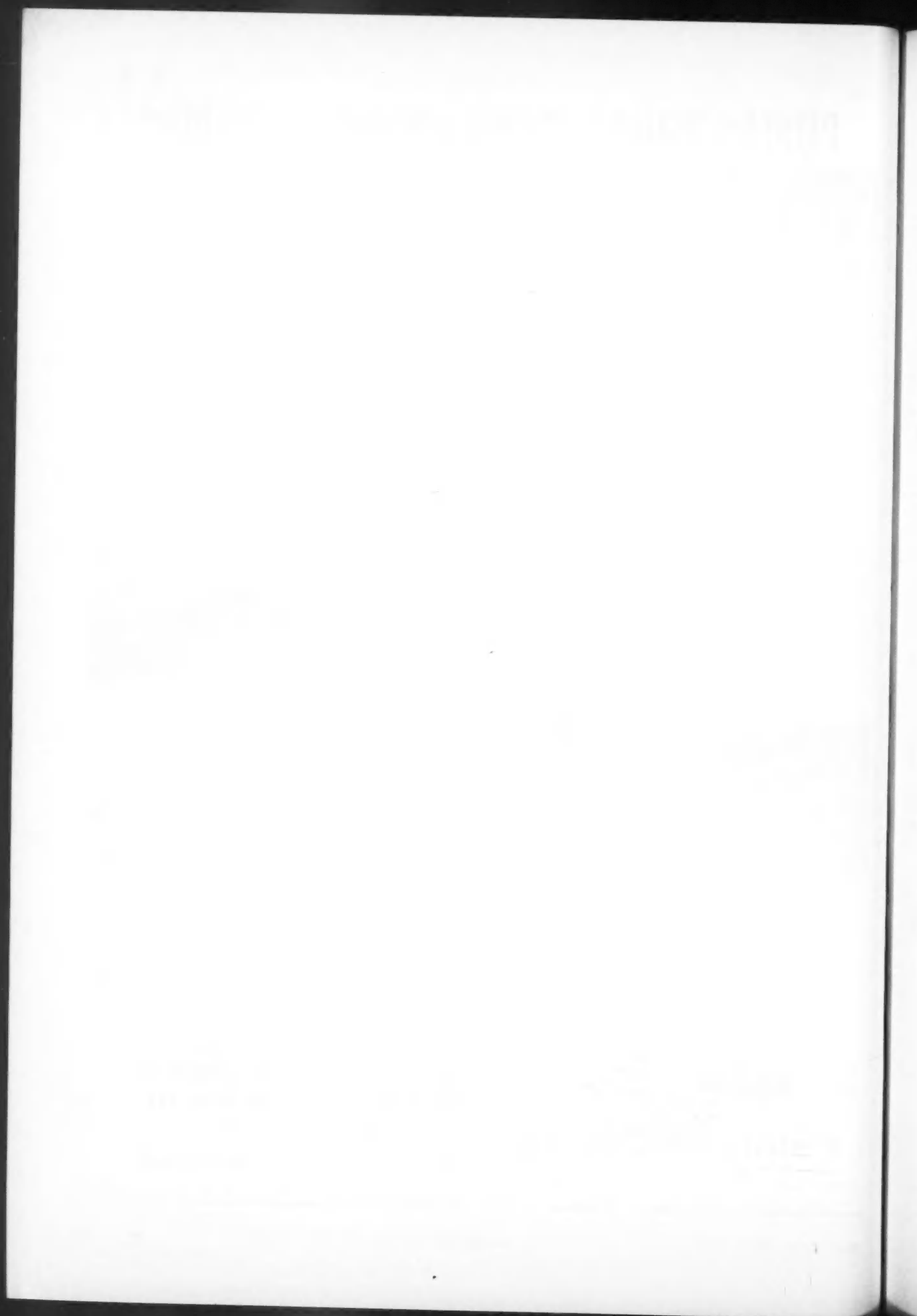
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Painton & Co. Ltd.
KINGSTHORPE NORTHAMPTON
Tel: 34251 (10 lines) 'Grams: 'Cell Northampton'

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★ Top Quality ★ Quick Delivery
★ Competitive Prices

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For protection against flame-failure



FLAME-FAILURE & IGNITION CONTROLLERS TYPES 700 & 701

*
**For gas or
oil-fired systems**

*
Completely reliable

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Extremely versatile

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LIMITED

These high-quality Controllers eliminate the dangers arising from flame-failure, and are effective in almost all types of gas or oil-fired furnaces. They employ an infra-red-sensitive photo-cell to 'see' the flame in furnaces, which discriminates between flame and furnace-radiation. The photo-cell reacts instantly to flame-failure and, should this occur, the fuel supply is immediately shut off by an electronic control unit.

Two Controllers are available. The Type 700 is semi-automatic (with provision for automatic purge cycle) and the Type 701 is a fully-automatic relight unit.

Other Controllers operating on flame-conductivity or flame-rectification, and complete installations, are also available.

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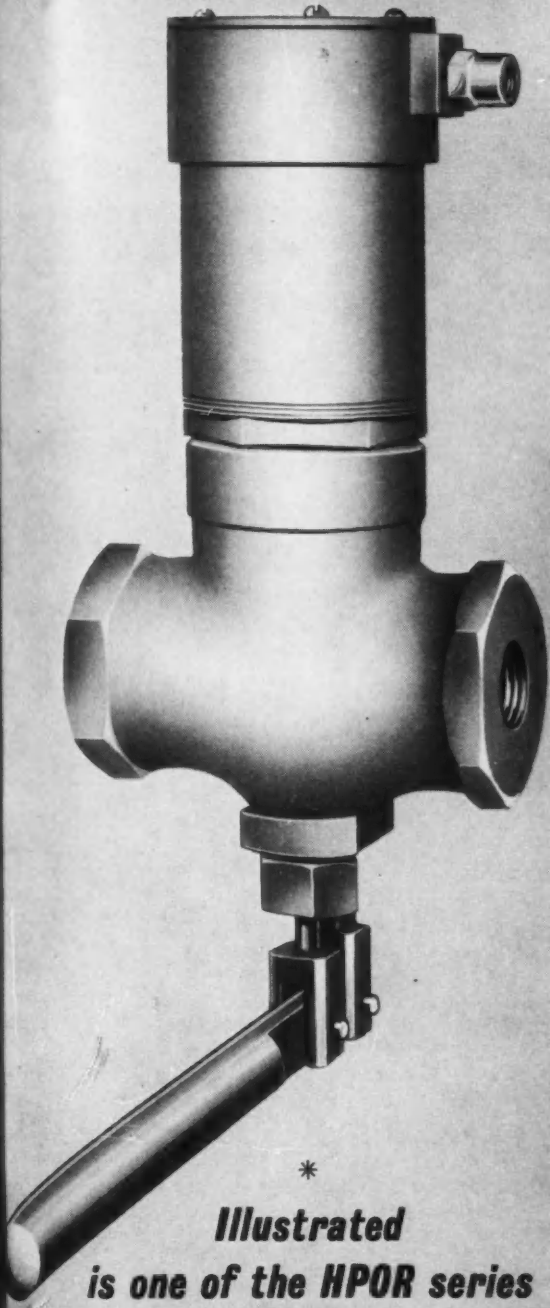
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to complete
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One of a range of highly-efficient solenoid valves, the HPOR is designed for use with all types of fuel oil. A lever mechanism ensures a smooth hand-reset operation. The valve is held open electrically and closes if the current fails. It will not then re-open until the hand-reset mechanism is operated.

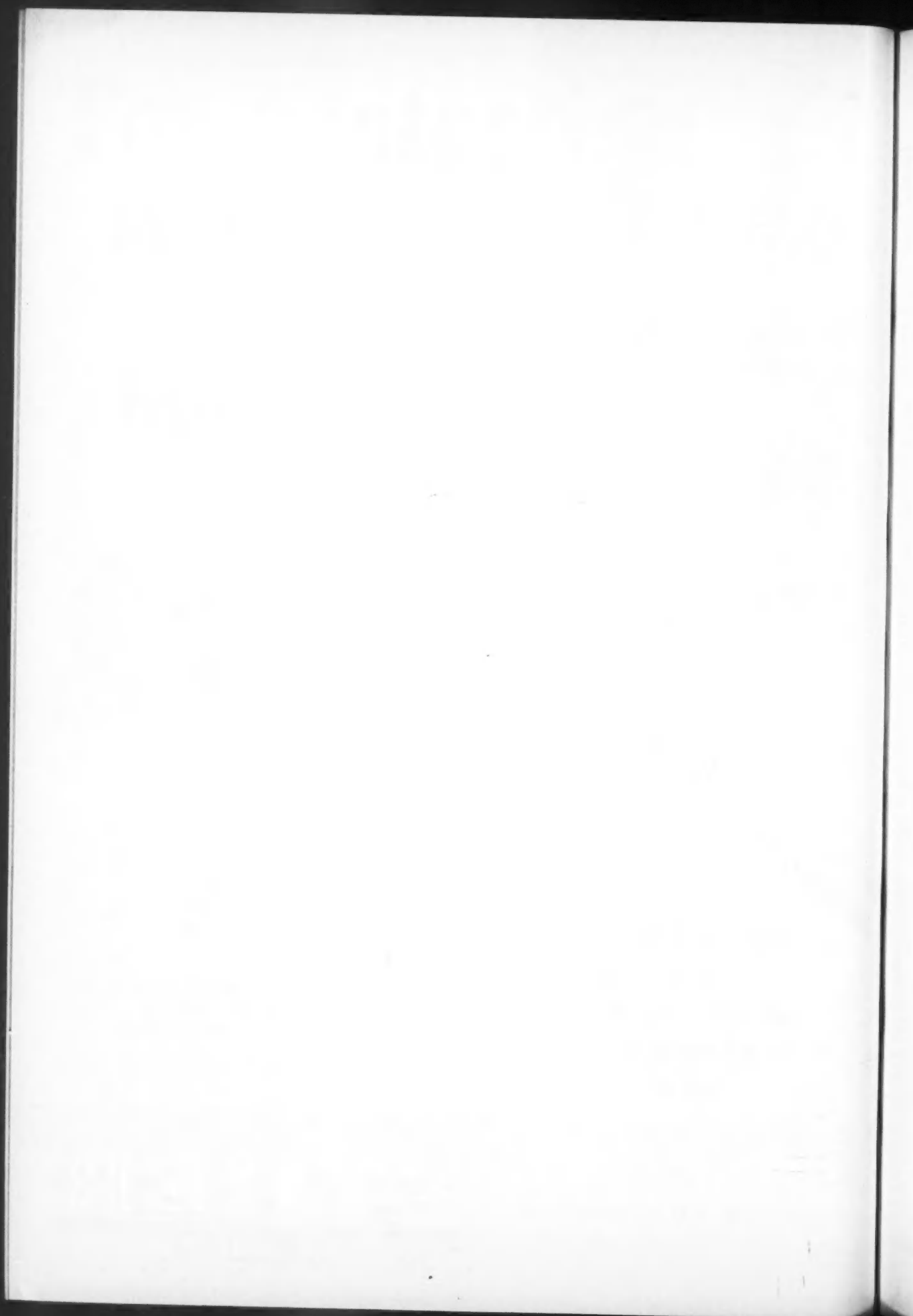
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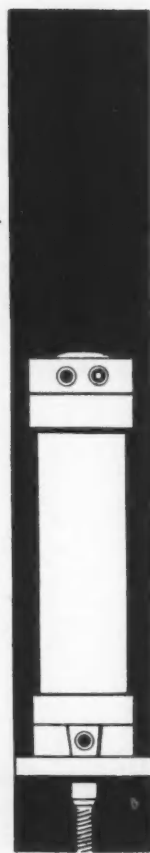
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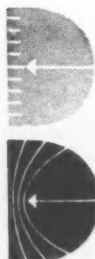
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on the Baldwin shop floor devote their attention to producing the superb finish, reliability and precision that characterises Baldwin Fluid Power equipment. There is a standard range of 384 pneumatic and hydraulic cylinders and over 700 control valves.

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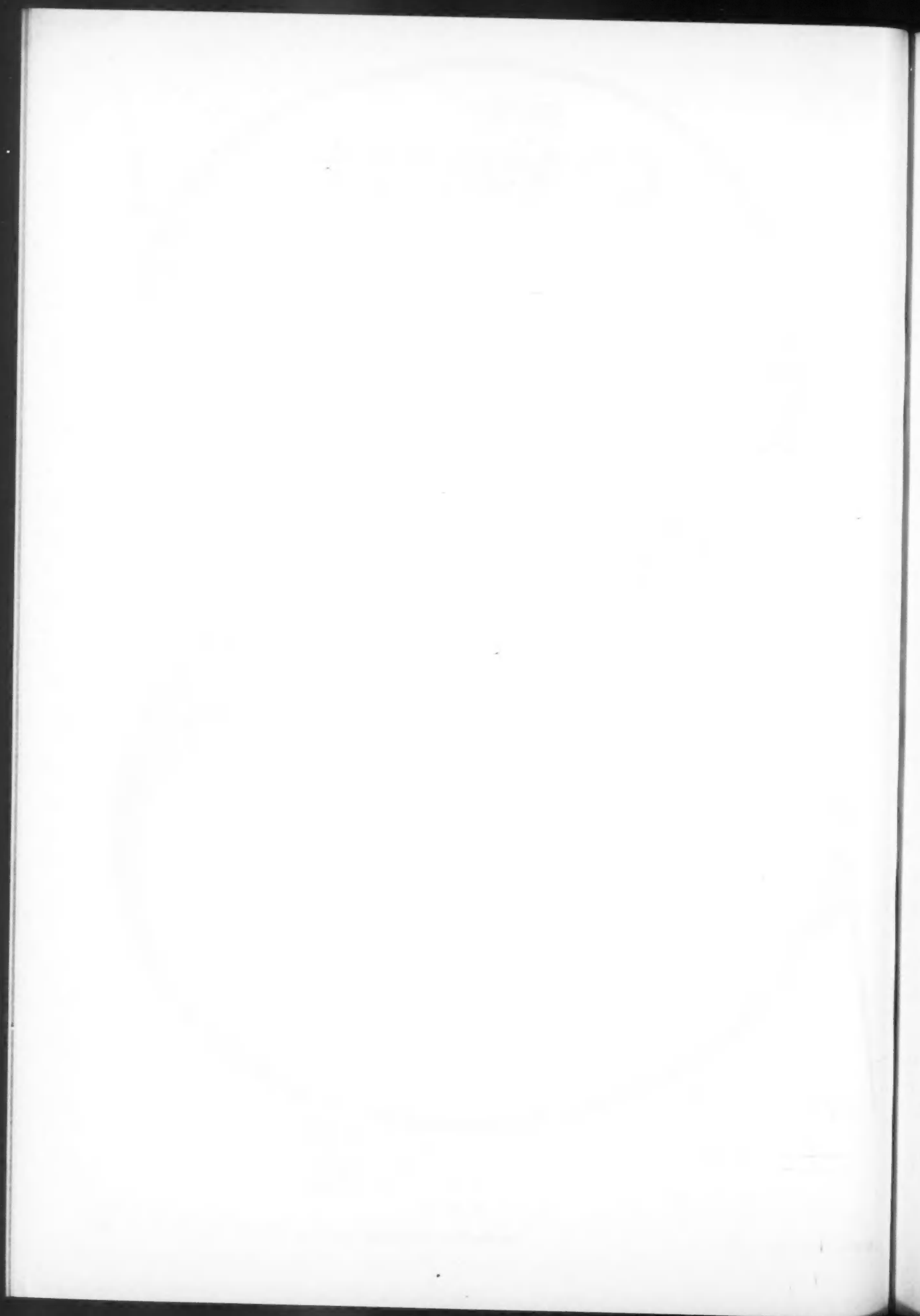
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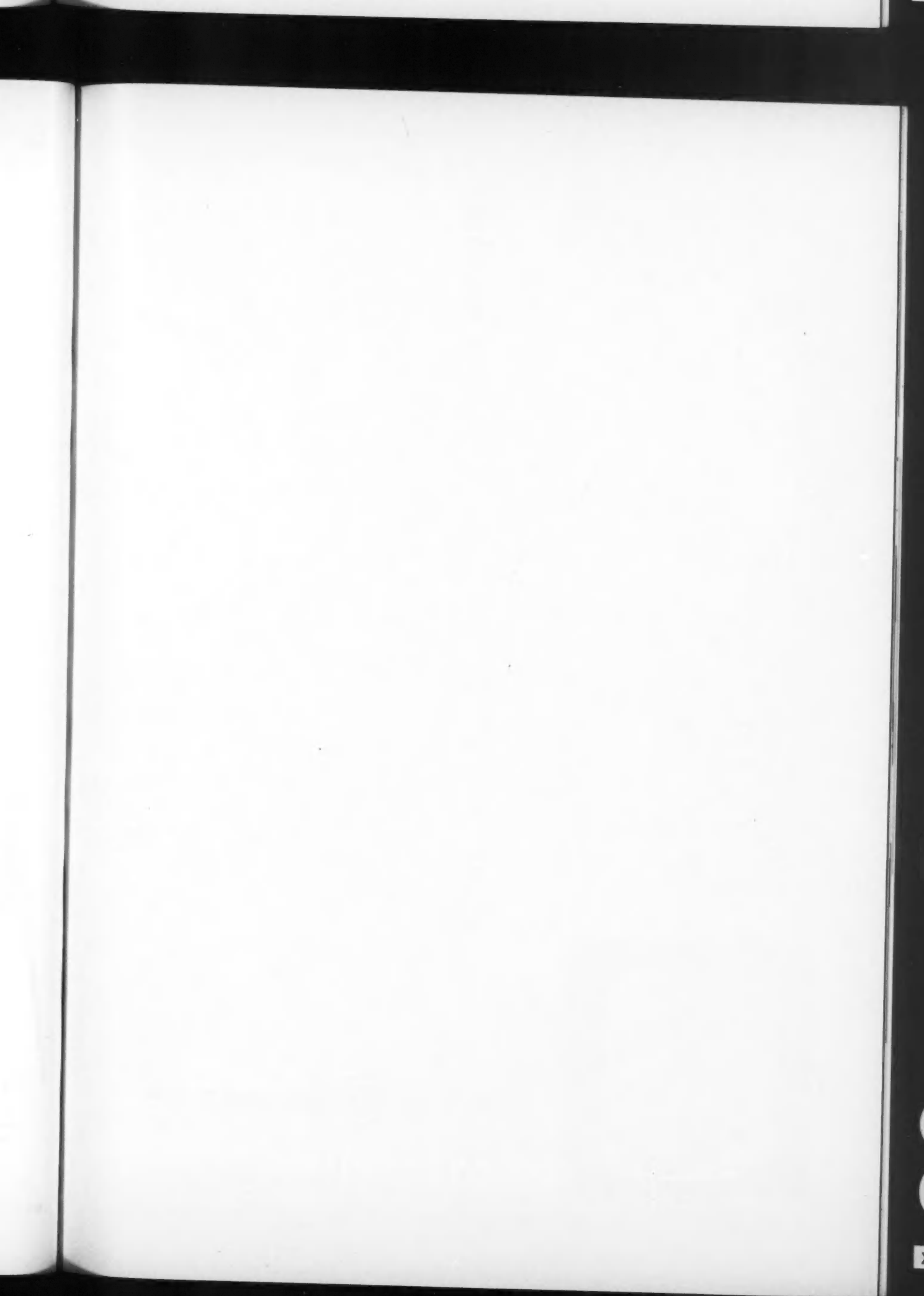
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THE GILBARCO FIRTH CLEVELAND TANK GAUGE is a highly sensitive electronic device for local and remote indication of the level of liquids—or liquid interfaces—in deep tanks of all shapes and sizes. It gives continuous readings of level for liquids of any specific gravity and it is accurate within a few thousandths of an inch—this is particularly important in tanks with a large free surface area.

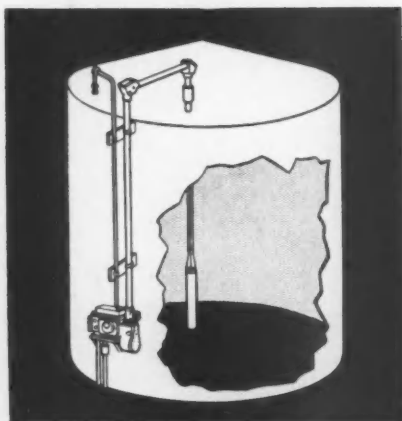
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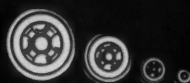
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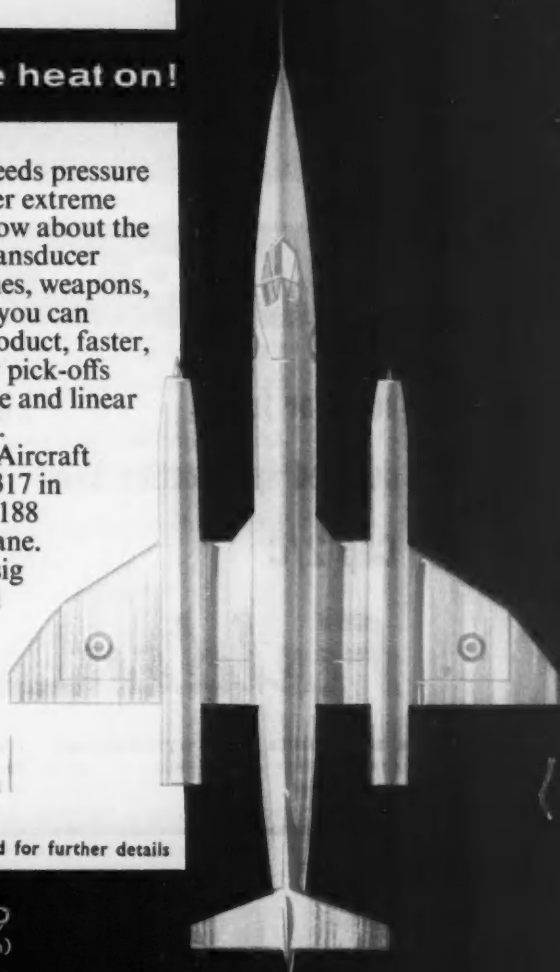
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low priced servo-operated
indicating recorder controller
for current or voltage

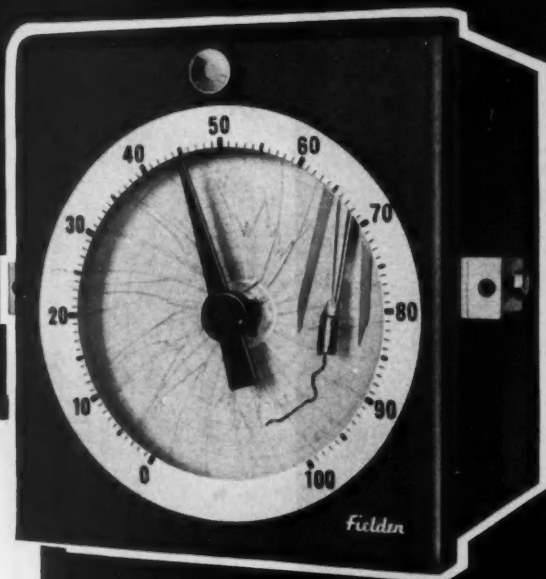
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- * AVAILABLE IN D.C. AND A.C. RANGES
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- * ELECTRICAL CONTACTS FOR ALARM OR CONTROL
- * VARIOUS CHART SPEEDS AVAILABLE

This inexpensive Servograph is fully transistorised and has a greatly simplified mechanism giving exceptional reliability. The pen and indicating pointer are motor driven and no errors are introduced by pen-to-paper friction, or by the weight of the pen.

The Servograph can record virtually any current or voltage, the minimum range being 0.25 microamps D.C. It is used with pH meters, Smoke Density Detectors, CO Indicators, Beta Gauges, etc., and for heavy currents can be supplied with current transformers or standard meter shunts.

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87



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The G-PAC MK II GENERAL PURPOSE ANALOGUE COMPUTER is the choice of the discerning engineer in all fields of industry for the solution of complex problems.

In the Chemical Engineering field.

- * STABILITY STUDY OF DISTILLATION AND FRACTIONATING COLUMNS
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- * HEAT TRANSFER

are examples of the wide range of applications in which G-PAC Mk II can considerably reduce days of tedious design study to hours.

For advice on problems—the long experience of the ELLIOTT ANALOGUE COMPUTING SERVICE is available to customers.

Enquiries should be addressed to:

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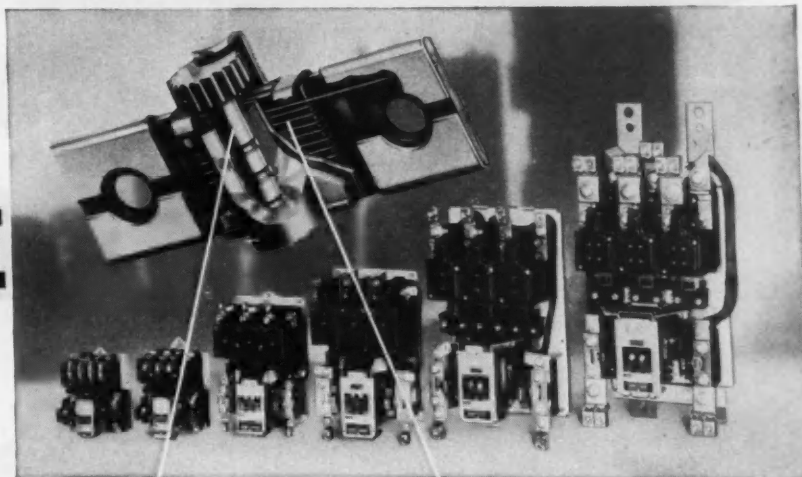
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YOU PAY FOR OVERLOAD PROTECTION

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Heat-responsive element
(solder pot) provides accurate response to overload, yet prevents nuisance tripping.

Heat producing element
is an integral part of overload unit. It's permanently joined to solder pot, can't become misaligned.

Only ONE-PIECE Overload Relays can give 100% Protection.

Only with ONE-PIECE construction can you *know* you've installed the heater correctly. Only with ONE-PIECE construction can you *know* the heater is exactly centred, or properly positioned, so that it performs according to its rating. Only with ONE-PIECE construction can you *know* your starters will not operate without the thermal units properly installed. Only with ONE-PIECE construction can you *know* your motors have full protection.

Only Square D has ONE-PIECE Construction. ONE-PIECE construction eliminates any possibility of heater misalignment. Square D melting alloy thermal overload relays can be installed only one way. They are tamper-proof. They are factory-assembled, are individually calibrated and tested. Repeated tripping will not affect their accuracy.

Insist on square D starters with melting alloy thermal overload relays

LET US PROVE IT!

Let your Square D Field Engineer show you 1 how one-piece construction is accomplished and how easy it is to mismatch separate heaters and solder pots — 2 a tripping time tester to compare various types of melting alloy units and to prove that tripping time won't change after repeated operation.



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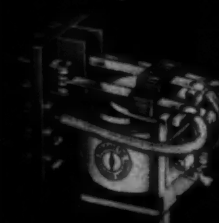
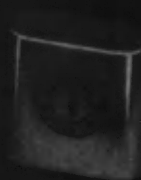
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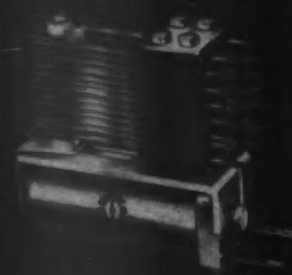
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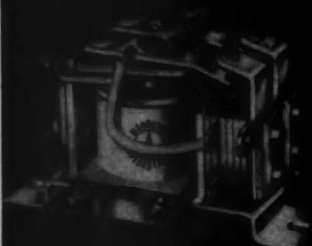
Relay	Max. D.C. Coil resistance	Max. Op. Voltage	Coil Loading	Max. Contact Rating
335	5,400	85	1.2 watts (max.)	2 amps.
315	2,500	48	1.25 watts	10 amps.
140 325	9,200	440 250	5 VA 2.5 watts	10 amps. at 30v. D.C.



Relay	Max. D.C. Coil resistance	Max. Op. Voltage	Coil Loading	Max. Contact Rating
185	12,500	250	3.5 watts (max.)	6 amps.
400	14,000	240	0.18-8 watts	9 amps.
105	40,000	250	80 milliwatts 10.5 watts	8 amps.



Relay	Max. D.C. Coil resistance	Max. Op. Voltage	Coil Loading	Max. Contact Rating
00 05	6,000 10,800	440 250	3-6 VA 1.5-3 watts	80 amps.
51 56	7,500 9,800	440 250	5-6.6 VA 2.6-3.3 watts	88 amps.
145	1,400	28	Independent of controlling supply	5 amps.



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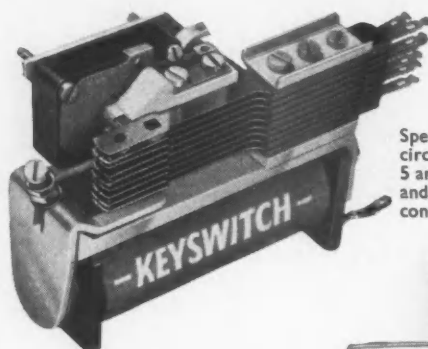
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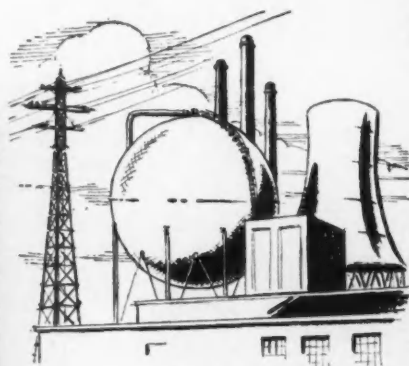
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Versatile and reliable, Keyswitch relays set the standard for design robustness, sensitivity and extremely efficient operation—even under the most hazardous operating conditions.

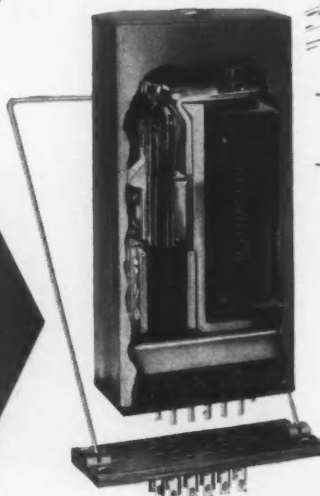
Special combined relay circuits fitted with 5 amps. micro switch and 9 standard 0.3 amp. contacts.



and now Plug-in 3,000 Type Relay

All the versatility and well established abilities of the best known relays in the world plus plug-in facilities.

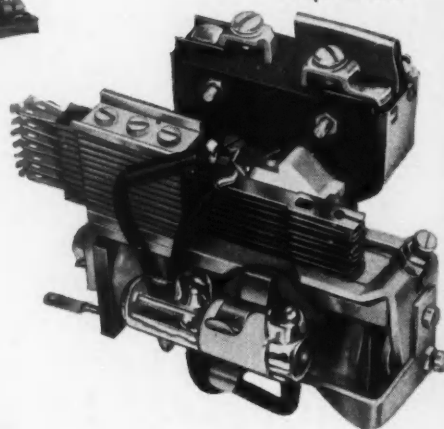
- ★ Positive contact between male and female pins.
- ★ Transparent or metal cover.
- ★ Clip retains relay positively in any position.
- ★ Contacts up to 18 light duty or 12 heavy duty.
- ★ Complete transistorized or A.C. units.



This relay incorporates 15 amp. Micro Switch, 5 amp. Mercury Switch and Standard 0.3 to 8 amp. contacts.



P.O. 600 Type (Minor) relay with a combination of heavy-duty and light-duty contacts for space and cost saving.



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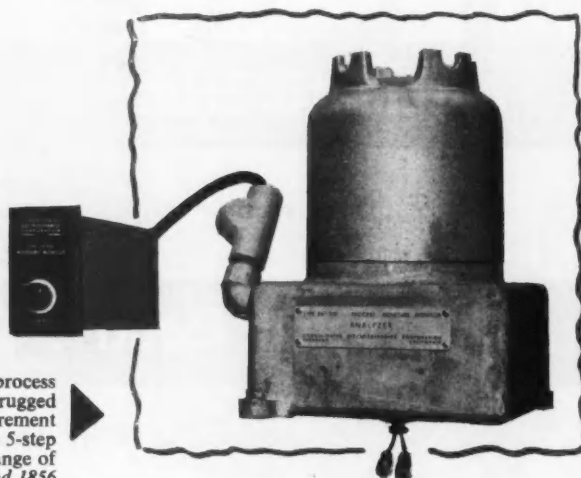
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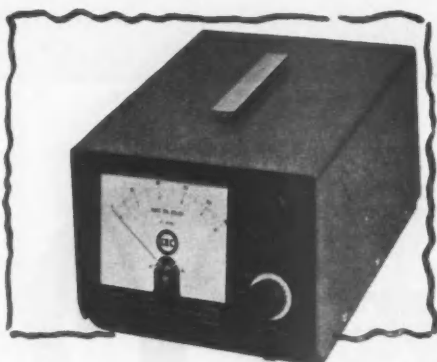
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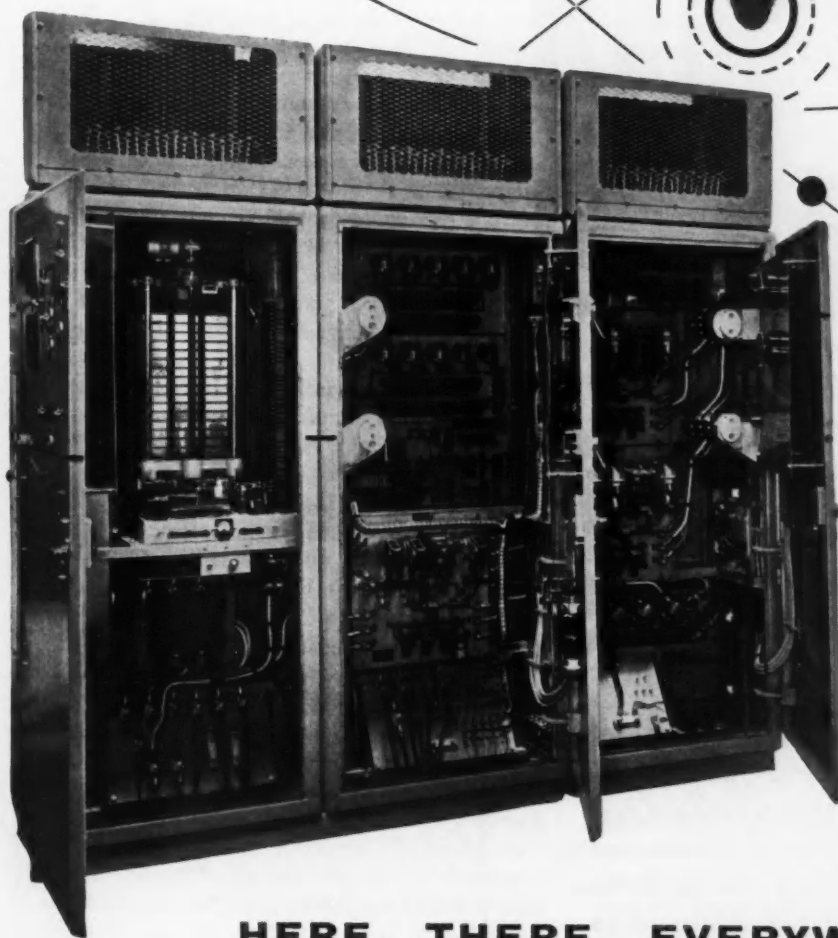
Quality Control Instruments Division

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Pelapone, backed by long experience in Automatic Rotating Plant, are able to offer Control Systems of high accuracy to meet specific requirements. Integrated Control Systems can be designed to cater for a wide range of inter-dependent Plant including mimic diagrams and remote indication units.

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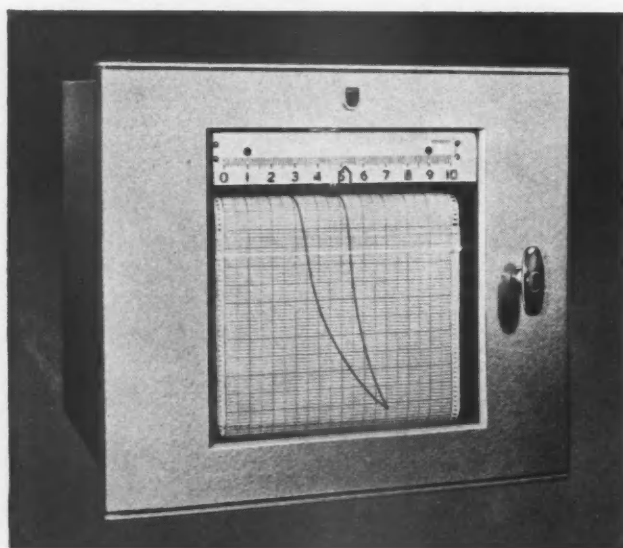
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Philips X-Y recorder PR.2220A/00 records the relationship between two variables which can be represented by small D.C. voltages. The unit consists of two completely independent measuring circuits operating on the automatic zero balancing principle, in which the pen is operated by one of the circuits and the chart drive by the other. Leaflet IM4-A12 gives full technical details — write for your copy now.

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Telephone: Terminus 2877

X-Y RECORDER TYPE PR.2220A/00

Zero-point position	at 0, 20, 40, 50, 60, 80 and 100% of the full scale
Accuracy	0.5%
Balancing force	Approx. 300 grams.
Damping of the servo-system	critically adjustable.
Bridge current	1 mA \pm 0.1%
Amplifier	A.C. amplifier, plug-in type.
Permissible input impedance	400 Ω /mV of measuring range selected*
Permissible D.C. voltage across input terminals and earth	1000 \times span, 100 V maximum*
Permissible A.C. voltage	across input terminals 0.001 \times span; across input terminals and earth 100 \times span*

* Criterion of reproducibility 0.1%.

Y-CHANNEL

Direction of pen movement	horizontal.
Graduation of scale	linear from 0 to 100.
Length of scale	250 mm.
Balancing time	1 sec. for full scale deflection.

X-CHANNEL

Chart travel	vertical upwards or downwards.
Scale	preprinted strip chart.
Length of X-axis	250 mm: after change of transmission ratio 360 mm.
Response time	2 sec.
Recording unit	ink container and capillary stylus for 0.3 mm line width: tear-off arrangement for recorded diagrams.

MEASURING RANGES

Y-CHANNEL	X-CHANNEL
0..... 5 mV	0..... 5 mV
0..... 10 mV	0..... 10 mV
0..... 20 mV	0..... 20 mV
0..... 50 mV	0..... 50 mV
0..... 100 mV	0..... 100 mV
0..... 200 mV	0..... 200 mV
0..... 500 mV	0..... 500 mV

The Philips X-Y Recorder is a Product of N.V. Philips, Eindhoven.

Thought for the future

WHENEVER an exciting new idea captures the imagination, popular acceptance tends to overshoot into absurd generalizations. Thus the ancient Greek geometers were so delighted with the logical beauty of their subject that they attributed triangular shapes to their elements, and saw remarkable philosophic significance in the perfection of a sphere. Again, now that men have some knowledge of how atomic nuclei behave, nuclear reactions have quickly been supposed to explain the sun and the stars, the passing state of the weather, and, most recently, the unfortunate change in composition that was experienced by Lot's wife. A contemporary of nuclear energy is feedback, and this too has suffered from the excessive zeal of the acolytes. We ourselves remember a lecturer whose sense of revelation was so strong that he would call feedback the fundamental principle of life—even of the universe.

Coupled with the concept of feedback, and deified not only by the multitude but also by some technical men who should know better, is that remarkable phenomenon automation. Indeed, there are those who say that feedback is the touchstone of automation, and that without it one has only paltry nineteenth-century mechanization. Recently we were privileged to hear a lecture by Professor A. G. Ivahnenko of Kiev—one of three delivered by him in the United Kingdom—in which he expounded a generalized approach that (although we hesitate to be emphatic after such a glancing acquaintance with it) appears to be an important contribution to control theory. The Professor dealt with what he called 'combined systems,' that is, systems in which both feedback and feedforward are employed. It would seem that combination in this way makes possible a form of controller that is much more like a human being in its behaviour than is a pure-feedback system.

With replacement of human labour as perhaps one of its greatest aims, automation is often said to promise the possibility of mechanical decision. Judgment in the future is to be exercised by computers that are really artificial brains, and these will be the dominant feature of control systems to come. In our March issue we published a most interesting article by Mr. R. A. Brooker of Manchester University. In this the author dis-

cussed some recent work towards the construction of such artificial brains, and suggested that thinking machines will be with us in a few years' time. This prediction has drawn the fire of one of our readers, and we publish his letter, together with a reply from Mr. Brooker, in the present issue. The dispute is not entirely a new one, but is not therefore less interesting. For our part, we have sympathy with both sides. We see no reason, *a priori*, why it should be impossible to construct an artificial brain, and we regard this as being in rather the same category as the artificial synthesis of living matter. It seems acceptable as a working hypothesis that only physical and chemical processes are involved, and that these will be mastered in time. But it would be another thing to say that we are already making machines that think. For thinking is a much wider activity than solving mathematical problems or answering questions set by an academic examiner. Mental activity cannot be entirely divorced from other bodily functions, and if an artefact is to 'think' in the same sense as a human being is said to do so, then that artefact must be a pretty fair imitation not only of a nervous system but also of a whole man.

Descartes is a philosopher well known to engineers for an invention that has been of untold benefit to them through the centuries. He, trying to take account of all the errors and deceptions that gross matter might inflict on him, queried every aspect of appearance down to what he considered to be the last unquestionable fact; *cogito ergo sum*, he concluded, *I think, therefore I am*. In our time, because machines that can do some brain-work undoubtedly exist, the Cartesian argument seems to have been reversed; these machines *are*, therefore they *think*. We suggest that it is dangerous to stretch metaphor into identity, and that for the sake of clarity it would be better if the verb 'think' were reserved for the human process. A machine may solve problems, answer questions—even ask them—but let us not say it 'thinks' unless it is a reasonably complete replica of a human being. Machines might supersede *homo sapiens*, as Mr. Brooker suggests, but that would be because of a degree of superiority in controlling their environment. To attain this they might need a system considerably less whimsical than the human process of thought, and perhaps in some ways fundamentally different from it.



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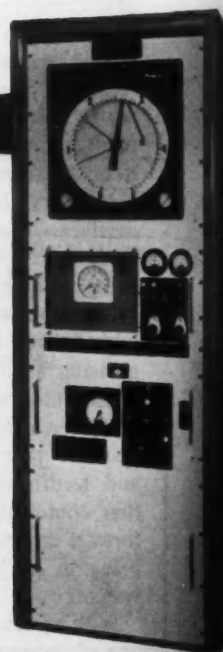
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LETTERS

to the EDITOR

Sum ergo cogito

SIR: I was very interested to read Mr. Brooker's article in your March issue. He seems to believe that a real thinking machine will be made before long, and his criterion of what constitutes 'thought' is the ability to fox an interrogator for five minutes. This I find hard to swallow! It is obviously possible, in principle, to store enough information in a sufficiently big and complicated machine to give it a sporting chance of answering all of an average interrogator's questions over any small and finite interval of time. I suggest that the minimum convincing interrogation period is one human lifetime—and even then I would not myself consider the case to be proved.

I was rather struck by your own remark, Sir, at the end of your leading article in the same issue, where you said that for practical purposes we must assume that we will always be ahead of the machines we create. You hint, oddly enough in parenthesis, at the only good criterion of a machine's intellectuality—its ability to supplant human beings in dominating the environment. This I think would be a wholly valid test, but I do not relish the thought of it.

Incidentally, I notice that the arithmetic is wrong in the conversation piece quoted by Mr. Brooker. Is there something subtle in this, or is it a slip of the pen?

South Kensington. D. IDWAL JONES

Mr Brooker writes:

'Much as one would like to question the "candidate" indefinitely, the fact remains that in real life situations such as interviews and oral examinations, the interrogator has to make up his mind in an hour or less. The question of the mechanism* involved is surely irrelevant: if the candidate can give satisfactory answers for the duration of the interview, then it is only polite to assume that he can think. One does not ask the candidate for a nervous diagram of his brain. To be sure, in the case of a human candidate one has written evidence in the form of testimonials and theses, but the machine can equally well supply such written "evidence", I could produce several such testimonials to our own machine!

As regards the arithmetical slip, I

*The machine's 'knowledge' will probably be stored in the form of 'trees' and the mechanism of memory some kind of 'reconstruction'.

guess Turing intended this to draw attention to the fact that the machine must bear in mind some of the human frailties. In other words if the candidate never made a slip of this kind, it would be sensible to infer that it was non-human!

On the question of whether we shall always be ahead of the machines we create, I think it would be wise to assume that we shall not—at any rate from the year 2000 onwards. I don't see that this need give us great cause for concern, after all most of us live or work in the presence of someone who is our intellectual superior, yet we do not necessarily carry around with us the burden of an inferiority complex. Nobody would penalize a man for not being able to add two numbers together in a microsecond, nor in the future do I think we shall regard ourselves as "inferior" if the machine takes over more intellectual tasks as well. Thus many intellectually gifted people are content to work for bosses who are not as clever as they are.

Finally as the editor pointed out, we may be at the end of our ascendancy in the evolutionary process, after all there is no reason to suppose that it will continue on biological lines: just as Neanderthal man was replaced by Homo Sapiens, perhaps electronic computers are destined to be the Inheritors of the Earth.'

(See also page 97.) —EDITOR.

Suspicious about electronics?

SIR: I have read G. M. Sturrock's article *Electric controls in the Britannia*, which you published in your February issue, with some interest and was particularly struck by his conclusions. He defends electric controls against the arguments of the enthusiast for lengths of steel wire very ably, but it is a defence for all that and not a downright statement that the modern electrical linkage is superior to its conventional mechanical counterpart.

One comes up against this sort of defensive approach to electrical—and here I include electronic—control time after time. There is, in my mind at least, little doubt that the electrical approach is in general far superior to the mechanical—hydraulic, pneumatic or what have you—system for the majority of applications. The usual reason for installing mechanical equipment is, of course, its presumed reliability. But are mechanical devices

really so reliable? And have present-day electrical controls such a bad record? The modern thermionic valve can more than stand comparison with the admittedly cunning but somewhat Heath-Robinson mechanical boxes of tricks with which industry is littered. Solid-state devices are even more reliable and may even, I understand, have an almost infinitely long working life. Reverting to the aircraft case, I suggest that the various black boxes making up an aircraft installation will be in good working order long after the aircraft has been scrapped.

This feeling that electronic techniques are suspect—a feeling which CONTROL does little to counter—dates from the plumber's-mate era of factory maintenance, and has little place in modern industry.

Trafford Park CHARLES RAMSEY
● We try to keep an open mind. Do any other readers feel strongly about this?—EDITOR

PUBLISHER'S COLUMN

More expansion

Readers sometimes imagine that we, as publishers, enjoy only a business appreciation of how well our journal is doing. Certainly we are gratified by the steadily rising circulation figures, and they do indicate how rapidly the popularity and influence of CONTROL are growing. But we also cannot help seeing the mounting piles of contributed material that are handled by the Editor and his staff. When we notice how some of this material is submitted—perhaps as a smudged carbon copy or a scrawled manuscript—we admire even more the professional patience of those who assess it. We know that they try to apply strict technical standards uninfluenced by poor presentation, but sometimes their judicial calm must be sorely tried.

The greater demand for CONTROL is of course partly due to the ever greater activity in the control field, and we are expanding the editorial staff to keep pace with it. This month we have pleasure in welcoming H. G. Bass, M.A.(Cantab.), an engineer with many years of experience. His career so far has included appointments with George Kent, the National Coal Board, and Heinz, and his outlook is as broad as a control engineer's should be. We wish him good luck in his new post.

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VIEWPOINT

R. E. Burnett, Managing Director of Marconi Instruments, discusses co-operation between Sales and Development, and asks . . .



WHO IS IN CONTROL ?

The difficulties involved in financing engineering design and development were discussed by J. N. Toothill in the February issue of *CONTROL*. He pointed out that large sums of money were now being spent in this way and it was becoming increasingly difficult to recover the investment.

In these circumstances it is clearly necessary to go to considerable lengths to ensure that money spent on research and development is used as wisely as the limits of human prognostication allow. Now that the comfortable days of widely spread government contracts are no longer with us, and competition in the markets of the world grows stiffer every day, these problems press increasingly upon us. It does, therefore, seem opportune to examine the way in which information and recommendations are collected and fed to top management to enable it to decide where money required for engineering development can be applied to the best advantage. Should we not give more attention to our methods of market investigation and product appraisal?

The desirability of directing our efforts to meeting, as nearly as possible, the real needs of our customers may well be obvious. Yet how often do our sales managers complain that the product designed by the engineering staff is not precisely what they require to meet the competition? How often do designers assert that the salesman doesn't appear to know early enough what is wanted—sometimes not until he has seen a competitive product already in a customer's hands? To secure the optimum co-operation between our salesmen and research and development engineers is a problem of the greatest importance, and the basic organizational and human problems involved require thought and examination.

Both sales and engineering must contribute their knowledge and experience to form a partner-

ship of mutual trust if reasonably accurate forecasts of product requirements are to be made. There are still some misguided die-hards who think sales alone should dominate the scene; equally misguided are the design and development engineers who think their responsibilities end when they have handed over a working prototype or a manufacturing drawing. A change in outlook is necessary. The increasingly complex problems obviously require of the engineer a high degree of technical knowledge and specialization, but to this must be married the salesman's experience of the market if top management is to be adequately advised on the likely trend of events and the probable requirements in three years' time.

In this article I have taken as an example the need for better co-operation between sales and engineering. I might equally have taken sales-production or engineering-production liaison, for all of these raise difficulties which ultimately affect the financial success or failure of an enterprise.

Compared with the speed at which technological advances have been made in the last twenty years, the study of organizational and management problems has advanced at the pace of the ox-cart. We must bring to our examination of the financial, organizational and administrative problems, the same enquiring and unprejudiced approach which we bring to our scientific problems. The obstacles are not all on one side, however, and some of our scientists and engineers must learn to recognise the importance of business problems.

I believe that those companies which are tackling these difficult organizational and human problems will eventually be amply rewarded.

R. E. Burnett

Last month the Institution of Mechanical Engineers met informally to discuss the computer in production, and those with actual experience in the field were invited to share their knowledge. We report some of the proceedings below

Computers applied

NO FORMAL PAPERS WERE PRESENTED AT A DISCUSSION on 'The Computer in Production' held at the Institution of Mechanical Engineers on 21st March last. There were three sessions, each opened with a few short remarks by selected speakers, and the general discussion was then begun. To help remove inhibitions among speakers from the floor, the Chairman asked that names should not be mentioned in the press. We shall therefore identify only the opening speakers.

The computer field

The proceedings began with a short talk by Sir Christopher Hinton, who thought it probable that we should spend several years trying to make engineers understand where they ought *not* to use computers, for computers were a tool of engineering and in no way a substitute for it.

Mr. A. W. J. Chisholm took the chair for Session 1, which was opened by Mr. Clifford Metcalfe (E.M.I. Electronics). From the very earliest days, said Mr. Metcalfe, people had been using models to represent nature, and sympathetic magic was among the first attempts to put models to practical use. Input devices, which could read the same documents as could human beings, would eventually simplify the preparation of data for computers. In a few years' time managing directors might be worried about redundancy in their profession; computers could already solve geometrical problems in the same time as a school-child.

'Should computer services be centralized or decentralized?' asked Mr. M. V. Wilkes (Mathematical Laboratory, Cambridge University), the second opening speaker. Production engineers were used to circumstances which favoured concentration into large units. In most such situations the economic advantages of concentration were relatively small, twenty or perhaps ten per cent, but in the computer case they were concerned with factors of two or three and perhaps as much as ten. The arguments for centralizing computer services were therefore very strong, and it was not true that a number of small computers could do as much work as a large one. There were two considerations weighing against concentration, fear of over-centralization and the prob-

lem of communication. Mr. Wilkes thought the fears were perhaps exaggerated. With regard to communication problems, they depended entirely on the amount of to-ing and fro-ing involved. Computers had their 'O.K. words': last year it was time-sharing, now it was data transmission. Many people were talking about a transmission of data along telephone lines, and the time would come when it would be possible to dial the nearest computing centre—dial another if that was engaged—and eventually present the problem to an available centre.

Economics and management

Mr. B. B. Swann (Ferranti) took as his theme the economics of computer working. He enunciated an empirical rule that the power of a computer, measured in terms of speed and storage capacity, was very roughly proportional to the square of its cost. It was therefore often much quicker and cheaper to run a problem on a powerful computer at a service centre. Only after some experience had they recognized that many small problems could be done on computers.

The last of the opening quartet in Session 1 was Mr. A. E. Taylor (Remington Rand). He was primarily interested in the use of computers by management. It was often said that binary computers could only answer 'yes' or 'no'. But often overlooked was the *missing* answer, for in normal commercial use one had not merely 'yes' and 'no', but also 'yes, but. . .'. A computer could not learn, although management required learning. It was becoming more and more possible to write programmes in English. These were inserted as instructions to the computer, and were completely understandable not only by the computer and the programmer but also by management.

The automatic factory

The first speaker from the floor described some experience at the Royal Ordnance Factory. Their approach had been from the concept of the automatic factory, which as they saw it had three components, production line, data-transmission system and computer. The

automatic production line was the result of mechanization. It was then possible to supplement the mechanization by computer-controlled machines, and the day would come when production lines would set themselves up as a result of machinations in a computer. Whatever the method of setting up the line there had to be instruments, counters, gauges and the like mounted on one or more panels. Here simple types of computer were employed. All previous speakers had referred to big computers, but he did not think that the smaller type was excluded. A computer was put in to stop the line if more than a certain number of rejections occurred consecutively. The computer or control brain could be set up in the office. After nearly two years of experience of such an installation he could say it had paid its way from an early date. Developments towards the automatic factory which they had in mind were built-in inspection and feedback, studies of the control panel and instruments with a view to standardization, electronic identification and counting, and computer-controlled material issue.

Process control

A speaker referred to some interesting developments on a sugar-beet plant at Wigginton with a very small analogue computer. It was an admirably simple device. Much could be done in any plant by putting in very small computers costing not more than £10 or £20. The meeting should not run away with the idea that large units were needed. A lot of money was required for equipment if it was not spent on brains, but if the money were spent on brains then less was needed for equipment. It was odd how many people would spend money on equipment and then think that they had done their duty and could go to worship on Sunday. The key to the computer in production was the sensing device, and there were not sufficient developments on foot in sensing, either in the discrete or in the continuous form. Coming back to the economics of computer work, in this country we could not afford to spend large sums of money on plant which we intended to use only for forty hours a week. We should always try to use a computer for at least 120 or 130 hours per week. If we could get it up to 200 hours per week, so much the better. We should use our capital equipment.

A speaker from chemical industry suggested that a moderate-sized digital computer, fairly slow, costing about £25,000 to £30,000, with not too much peripheral equipment, might well serve 29 to 30 engineers. It represented an investment of about £1000 a year per engineer, which was more expensive than a slide-rule. In his experience the engineer of to-day needed this £1000 per annum spent on him in order to make his work more productive.

Data processing

Mr. L. Landon Goodman took the chair for the second session and invited Mr. J. A. Goldsmith (partner, Robson, Morrow & Co.) to begin with an overall

survey of data processing problems in production. After a few general remarks Mr. Goldsmith quoted the case of an electricity company in the U.S. which was just now planning to use a computer to switch generators on and off according to the load. Here the computer would be used completely to control all the power stations, and even to feed electricity automatically to outlying districts. This was the case of a computer controlling not only the planning of production, but also the correction of a plan, and it was actually operating on the shop floor.

Mr. Goldsmith concluded with an example of a computer advising management, and he was followed by Mr. P. J. Macleod (I.C.T.), who was invited by the Chairman to say what he thought about the computer going one stage further than advising, and in fact taking over. Mr. Macleod's response to that was absolute horror. He thought computers had suffered from their advance publicity. Many regarded them as enormous soulless boxes, doing complicated mathematical calculations of a kind in which the vast majority of us had had only a cringing interest at college. Computers of the large mathematical type were not for him or for the majority of people who worked with him, or who worked in any other factory. 'Black box,' a term which had been applied to computers, was a bad term because it usually meant magic, and magic meant not only secret delights but also some secret failures. You got the idea when listening to some conversations about computers that they were a sort of 'Big Brother' who was watching you, and that if your efficiency dropped 1/10 of 1% it would tell someone—and what was more, tell someone behind your back. That might be a common experience in industry, but you did not have to buy a machine to do it. Computers were simply machine tools that could carry out simple arithmetic very fast.

Mr. Macleod said he felt that the idea of computer planning in a factory was terribly important to British industry. He invited the audience to think of their desk drawers in their offices. He was sure that nine out of ten of them could build fascinating mechanisms out of what was in those drawers and on their windowsills. He himself could almost build an automatic telephone exchange with his. All that represented work which ought not to have been done. We beefed about British industry being unimaginative, he went on, and we blamed this on lack of risk capital. He would say that, in ten years' time, when computer control was as common as he thought it would be, and when we could really make sure that we did not make things unnecessarily or before we actually needed them, then any large-scale industry would be able to take some of those chances which it ought to take—and would have to take if we were to survive as an industrial nation.

Electronic image of the factory

Mr. R. T. Harrison (I.B.M.) said that computer methods based on file processing techniques, although a great step forward in speeding up production control,

were still far short of the ideal. The greatest benefits accrued from use of a computer able to simulate the processes of the shop floor by storing all the many varied but nevertheless interrelated records internally, and able to accept feedback information at random to keep such an electronic image of the factory right up to date. If it was possible to keep a complete description of all factory processes within the computer, not only did semi-automatic procedures become practicable, but the situation might be examined partly or wholly at any moment, and projected into the future so that difficulties might be foreseen and guarded against. Such a system pre-supposed a computer with a very large random access storage, and Mr. Harrison described plants for controlling the production of a medium-sized light engineering firm, mass-producing electrical appliances.

Mr. G. D. Royle (English Electric) concluded the opening section of Session 2 with a description of the real time computer control of a hot saw in a steel mill. Mr. Royle showed that on the basis of observed figures it was possible to obtain 2 or 3% increase in yield by incorporating an electronic computer in the system. The increase sounded small, he said, but when it was realized that the production of section from one finishing stand might be of the order of 100,000 tons of steel a year, the 'small' increase became significant.

Small pioneer

Another contributor felt that his company had been to some extent a pioneer in this field since it had been using computers for production and stock control for just over four years. It was only a small textile firm of between 500 and 600 employees, so they could not afford long development programmes. Since they were still using the computer, the audience could take it that it had paid. They had started out by taking one application, the biggest problem—production and stock control—and worked on that. They had added a programme for the planning of raw-material buying, involving analysis of total order-book position. The next stage was to add a programme for sales forecasting, which had worked out quite successfully this year. By combining the output from the sales forecast and the outputs in respect of raw material, man-power and machine planning, they had been able to make a forecast permitting them to take a bit of a chance. They had gone into production in the factory at least four weeks before getting sufficient orders to start in the ordinary way. This would give them an 8½% increase in production for the year. They were now working on the next stage. This was a programme of cost estimating. When they had finished that, they intended to produce their accounts also. So far they had reached the stage where they could value their stock. They could get a complete stock valuation within a couple of days of stock-taking, rather than three weeks or a month afterwards as before. The computer was ideal for the pay roll if one had enough employees. It was not so good with only 600 employees.

However, as long as they were using the computer anyway they might just as well spend a few extra minutes in doing the pay roll. By constantly working on the problem they had reduced their average time (at a service centre) from a week to only an hour. This cost them something like £25 per week.

Chipping and butchering

Session 3, under the chairmanship of Mr. A. W. J. Chisholm, was opened by two speakers, Mr. K. Teale (Short Bros. & Harland), who discussed the development of numerically controlled machine tools, and Mr. C. F. Steventon of British Oxygen Gases, who, with the aid of a short film, described a computer-controlled flame-profiling machine.

Answering a question, Mr. Steventon said that as far as the ship-building industry was concerned it was a great deal easier, because of the size of the profiles, to use the digital system. The advantage of this was that they could have a programme from ordinary workshop drawings. In another reply, Mr. Teale pointed out that they only gave a machine a thirty-minute check at the beginning of the work. They had found that the mechanical side of the machine was far more efficient with programme control attached.

The Chairman thought that many of the audience would be interested in a picture of machine shops in fifteen years' time, and invited the speakers to tell them how things would look in the jobbing shops for instance. Mr. Teale answered that he did not anticipate differences in the next few years, but tape control was a jobbing-shop function and not a mass-production function. He thought that they would see more tape machines in the shops.

A speaker added that they had so far kept the discussion going very much along the lines of chip production and butchering. Obviously they were interested in producing at the lowest possible cost. They could use numerical controls on many other machines than those which cut and carved. They also had tape-controlled welders, tape-controlled transfer lines and tape-controlled assembly machines. Most of the problems of manufacture seemed to occur in assembly. Tape-controlled assembly was the answer. It could be used for batch production and mass production.

A speaker rose to express entire disagreement with these remarks. It was wrong to say that assembly was the source of the trouble. It was possible in any factory to obtain very great output providing the stuff was there at the right time and in the right quantities. He had been surprised to hear an earlier remark that tape-controlled machines would only come in for jobs with a complex profile. He understood that in the U.S. machine tools used for quite ordinary jobs were now frequently controlled by numerical systems. If labour rates continued to go up, then these systems would become more economic in the next ten years.

A full report of the meeting and the discussion is to be published in the Proceedings of the Institution.

Analogue-computer analysis of rolling-mill controls

Very soon the engineer will not consider using a mathematical model unless the answer is obvious. Not only the very big companies, but also many smaller ones will come round to this way of doing things

by **R. B. LARKINSON, M.A. (OXON.)**

English Electric Co. Ltd.

Last month we showed how servo-mechanisms are analysed in two stages, and explained the disadvantages of such mathematical analysis. We described the functioning and the basic units of a computer, and began a discussion of transfer functions. At the end of Part 1 we were considering the voltage control of a main drive generator.

The equations for the generator are

$$\left. \begin{aligned} V_{GE} &= IR + N \frac{d\phi}{dt} \\ V_{GEN} &= K\phi \end{aligned} \right\} \text{where } \left\{ \begin{aligned} V_{GE} &= \text{Exciter volts} \\ I &= \text{Generator field current} \\ R &= \text{Generator field resistance} \\ N &= \text{Number of turns in field} \\ \phi &= \text{Flux} \end{aligned} \right.$$

and $\phi = f(I)$

This can be represented by the block diagram shown in Fig. 8.

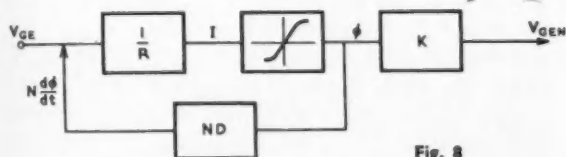


Fig. 8

The relationship between I and ϕ can be simulated by a unit which uses between ten and twenty amplifiers, the working range of which is controlled by biased diodes. Thus the relationship illustrated in the equations can be obtained. It should be noted that in order to obtain a signal proportionate to the rate of change of generator flux a capacitor feedback will have to be used.

Amplifier 9 is for obtaining a signal proportionate to the rate of change of generator exciter volts, this signal being used for stabilizing the exciter voltage limit control, which has its reset through amplifier 10. Amplifier 11 will provide the necessary dead zone characteristic of this control.

Some curves of the responses obtained with an analogue similar to this one are shown in Fig. 9. The responses of the various units are shown, and also the

effects of too much and too little stabilizing. The three different curves of the response of the generator voltage can be obtained in a period of seconds by switching resistances in a computer, whereas with a slide rule their determination would probably take as many hours.

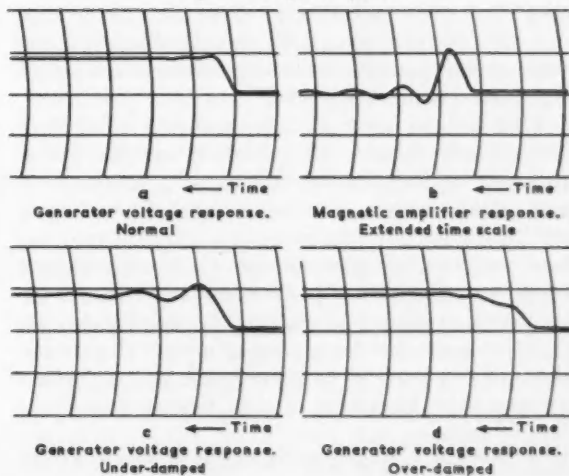
If we consider the problem of controlling the electrodes of a liquid regulator of an Ilgner set we have the relationship

$$I = \frac{K(N_0 - N)}{R}$$

where I is the rotor current, N_0 synchronous speed, N running speed, and R the rotor resistance. In this equation there are three variables, and in order to obtain N we must be able to form the product of I and R . This cannot be done with the basic units of the computer but requires two squaring units which will square respectively the sum and the difference of I and R . A quarter of the difference of the outputs of these units will give the required product. This multiplier unit is one of the more complicated computer elements.

Other units can be arranged so that they perform switching operations when either a certain portion of

Fig. 9 Analogue responses



the time cycle has elapsed or when a certain variable in the analogue reaches a certain value. The former characteristic is useful in analysing servo-mechanisms into which relays have been incorporated as amplifiers. The latter characteristic can form the analogue of graded rheostatic braking.

Analogue accuracies

It can be seen from equation 1 that the inaccuracy introduced by assuming infinite gain is of the order

$$\frac{\frac{V_o}{KR_1} + \frac{V_o}{KR_2}}{\frac{V_o}{R_2}} = \frac{1}{K} + \frac{R_2}{KR_1} \times 100\%$$

If we have more than one input with associated resistances R_{11} , R_{12} , R_{13} etc. the inaccuracy will be

$$\frac{1}{K} + \frac{R_2}{KR_{11}} + \frac{R_2}{KR_{12}} + \frac{R_2}{KR_{13}} \times 100\%$$

Now K will be of the order of 10^4 at a minimum, and obviously it is desirable to keep R_2 as small as possible compared with R_{11} , R_{12} , R_{13} etc., i.e. the gain should be kept as small as possible. Ordinarily the maximum number of inputs to any amplifier will be three and the gain should be kept below ten.

With this set-up the inaccuracy of the output would be

$$\frac{1}{10^4}(1 + 10 + 10 + 10) \times 100\% = 0.31\%$$

From the foregoing results it can be seen that to keep the inaccuracies to a minimum the overall gain of the servo-mechanism should be distributed over as many amplifiers as possible. However, care should be taken when moving gains in a system where non-linearities exist, as the effect of the non-linearity will normally depend on the amplitude of the input, which will depend on the positions of the gains in the system. It can generally be stated that the effect of inaccuracies in the computer will be less than 1%, and since, for the systems considered, some of the component characteristics are not known to an accuracy greater than 5%, the effect of the errors will be negligible.

Conclusion

Eventually it will be realized that if there is an equivalence relationship which links long multiplication with mathematical models, then that relationship links logarithms with digital computers and slide rules with analogue computers. No engineer to-day would consider using long multiplication unless the answer were obvious; he would use logarithms if a high degree of accuracy was required, and for most purposes he would use a slide rule. Similarly, very soon the engineer will not consider using a mathematical model unless the answer is obvious; he will use a digital computer when a high degree of accuracy is required, and for most purposes he will use an analogue computer.

Acknowledgment:

The author wishes to express his acknowledgment to the English Electric Company for permission to publish this article.

... from steel to hydrogen peroxide

DURING THE DESIGN OF A LARGE, CONTINUOUSLY working plant for making hydrogen peroxide, the mass flow round the system was simulated on an electronic analogue computer. This application was described in a paper read to the Society of Instrument Technology last month by A. H. Doveton (E.M.I.) and K. C. W. Pedder (Laporte Industries).^{*} The authors concluded that it is extremely difficult to attach any concrete monetary significance to such an experiment, but they were careful to explain what they meant by this apparently non-committal statement.

They had no doubt that the analogue technique is outstandingly valuable when used on complex control problems, adding that it often permits developments that would otherwise not be considered. Except in one particular case, the researches they had described had been concerned not only with specific control problems, but with confirmation of performance predictions covering the whole plant. The costing of the investigation had therefore to account for starting-up delays, shut-downs, and losses of liquor or production time that might have occurred if no knowledge of plant behaviour had been

won during the investigation. It could be said that the cost of the computer project had been about 0.1% of the cost of the complete plant—roughly one day's production cost—and in the authors' opinion the investigation had been 'a very realistic investment.' Indeed, as they pointed out, the determination of optimum controller settings alone could easily repay the whole cost of the research, bearing in mind the many interruptions and upsets that normally occur during the adjustment of controllers on such a chemical plant.

The authors went on to say that subsequent experience gained by the computer industry in process control problems has been such that a large portion of the costly mathematical preparatory work is no longer necessary. It has been confidently estimated that a similar investigation to-day would cost less than half what it did in 1957.

Finally, the authors suggested (much as Mr. Larkinson has done in his Conclusion above), that analogue-computer technique can, and almost certainly will, become widely used—not only by the very large companies with highly qualified technical staffs, but also by many smaller organizations that now regard such endeavours as beyond them.

^{*} 'The Simulation of a Large Chemical Plant on an Electronic Analogue Computer,' read on March 16.

PART 3

Load cells in industrial weighing

by **R. B. SIMS, B.SC., PH.D., M.I.MECH.E., A.INST.P.**
Davy and United Engineering Company Limited

In Part 1 (February) we wrote the general equations for e.r.s.-gauge load-cells. Analysis of errors due to e.r.s. gauges, begun in Part 1, was completed in Part 2 (last month). We then discussed in detail the errors that can arise in design and application. This discussion is continued below.

A commonly accepted value of the output ratio V_m/V_n (see equation 5) of a load cell is 2 mV/V at its maximum rated load. When the elastic measuring element is machined from a heat-treated steel forging, a stress of approximately 20 ton/in² is required in it at maximum load to produce this output ratio. A load cell of this type, designed for five tons maximum load, must have a measuring column of 0.25 in² (152 mm²) in sectional area, or a diameter of 0.565 in. (14.1 mm) only. In the general case, suppose that a side thrust of P tons is imposed on this cell, in which the measuring column has a yield stress of Y tons/in², and the axial force F gives rise to a compressive force of $\tau = F/\pi r^2$. The load cell is considered to be firmly bolted to its foundations. The maximum stress in compression and bending at the root of the column is then

$$\sigma = k_1 F/\pi r^2 + k_2 \frac{4Ph}{\pi r^3} \leq Y$$

where k_1 and k_2 are the stress concentration factors at the root of the loaded column. Alternatively

$$\sigma = \tau k_1 + 2k_2 \frac{P}{F} (h/2r) \leq Y \quad \dots(8)$$

In a 5-ton-capacity load-cell, practical engineering considerations predicate a minimum height of about 2.5 in. (62.5 mm), and the height is usually much greater, so that $h/2r \geq 4.5$. If $Y = 50$ ton/in²; $\tau = 20$ ton/in², and conservative values are assumed for k_1 and k_2 at the maximum load, the limiting side thrust is less than 0.2 tons. The load cell would, therefore, be

In the form of standard packaged units, properly installed load-cells give accurate results—without need for precise alignment of structure or elaborate foundations

reasonably accurate since it has a large height-to-diameter ratio, but it would be capable of withstanding only very small side-thrusts.

Side thrusts

Side thrust on the elastic measuring element may be reduced in various ways. It is possible, for example, to build diaphragms into the load cell between the measuring element and the stiff outer case, but in column-type load cells this technique is of limited value, since the stiffness of the diaphragm in the horizontal plane is limited if linearity in the cell is to be preserved, and then the column will usually reach the elastic limit before the diaphragm. An alternative technique is to absorb the side thrusts by a system of tie rods on the structure to which the load cells are fitted. In some installations tie rods cannot be avoided in any type of cell installation, especially when a large tank is exposed to heavy wind loads, but tie bars should not be relied upon to remove all side thrust, and some residual thrust will remain, the magnitude depending on the relative stiffnesses, or compliances, of load cell and ties. Tie rods are, moreover, relatively expensive to install.

A sounder approach to the problem is to design the load cell to withstand relatively large side-thrusts, and to be insensitive to the distribution of the load. Fig. 10 illustrates the toroidal load cell designed by Newberry (11). The measuring element consists of a tube bent into the form of a ring, or toroid. Four gauges are bonded to the horizontal diameters of the toroid, two on the inside diameter which are compressed under load, and two on the outer diameter which are stressed in tension. The four gauges form a Wheatstone network similar to that shown in Fig. 2. The load cell is technically and economically sound for load ratings over the range 0.5 tons to 200 tons, and possesses a number of attractive features. Its height is small, it has a

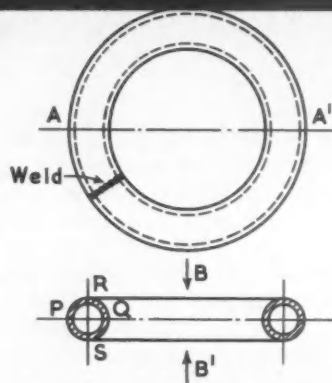


Fig. 10
Toroidal load-cell
designed by
Newberry



large loading area so that localized loads do not cause cracking, it is almost completely insensitive to the distribution of load, since the peripheral e.r.s. gauges integrate the strain, and, when carefully designed and manufactured, its output is strictly linear with load. Fig. 11 shows an industrial version of Newberry's design. The overall height for a 1.5-ton-capacity load-cell is only 2.375 in. (59.2 mm) and the 50-ton load cell is only 2.75 in. (69 mm) in height. The industrial design incorporates an ingenious system of internal horizontal struts which enables the smallest load-cell to withstand a side thrust of three tons and the largest a side thrust of up to 22 tons without risk of mechanical damage or without affecting the measuring accuracy.

Another design for loads below 100 tons is the Davy-United precision load-cell. The design is shown in Fig. 12 and covers the range from 3–100 tons. A section of this type of load cell is shown in Fig. 13. Completely uniform stress is obtained in the elastic measuring element by the folded internal construction which gives it an effective height/diameter ratio of 15:1. Load is applied to the weighing sleeve by a self-aligning push rod, and the sleeve is supported in a massive

Fig. 11 Industrial version of toroidal load-cell for which a Certificate of Intrinsic Safety has been granted



water-cooled jacket. The element, which is supported against side thrust by a system of internal struts similar to that used on the toroidal cell, is not only completely insensitive to the method of loading (as predicted by St. Venant's Principle), but it is also linear to the $\pm 0.02\%$ level at least. Load cells of this design, which have inbuilt water cooling, have been used to measure jet-engine thrusts to an accuracy of ± 10 lb in 30,000 lb with long-term stability.

The toroidal and precision cells will between them cover a loading range down to 0.5 tons, but for conveyor-belt weighing it is frequently necessary to measure loads as low as 56 lb (25 kg) and there are many tank-weighing applications where the loads in the range 0–2 cwt (0–100 kg) must be measured with accuracy, particularly in works laboratories to calibrate flowmeters. Two designs are possible, a ring-type load-cell as shown diagrammatically in Fig. 6, or a cantilever, or a beam. The difficulties associated with the ring design have already been discussed, and an accurate instrument is difficult and costly to manufacture. Apart from cost considerations, the ring-type load-cell cannot be designed to carry side thrusts of more than about 50–80 lb. When used on conveyor belts, however, considerable side thrusts may develop quite suddenly if an idler bearing becomes stiff or seizes, imposing a heavy drag on the roller and the load cell, and it is for this reason that the beam type of cell is preferred. The dimensions of the beam may be chosen so that it is very stiff indeed in the horizontal plane whilst sensitive to quite small vertical forces. By a careful choice of bridge networks, and by correct design of the beam

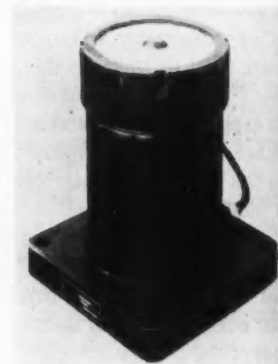


Fig. 12 Davy-United precision load-cell, also covered by the Certificate of Intrinsic Safety

supports, this type of cell can be made almost completely insensitive to the method of loading. The resulting cell is a rugged instrument capable of withstanding the arduous conditions in which belt conveyors usually work, whilst capable of surprisingly high accuracies. A weighbeam which was built for a flow laboratory (shown in Fig. 14 without its protecting cover), will indicate accurately to better than 200 g in a total of 500 kg, over the complete span of its scale, without any modification to the standard potentiometric-type indicator used with it, other than fitting a manually operated scale expansion.

The column type of load cell, shown in Fig. 8 and

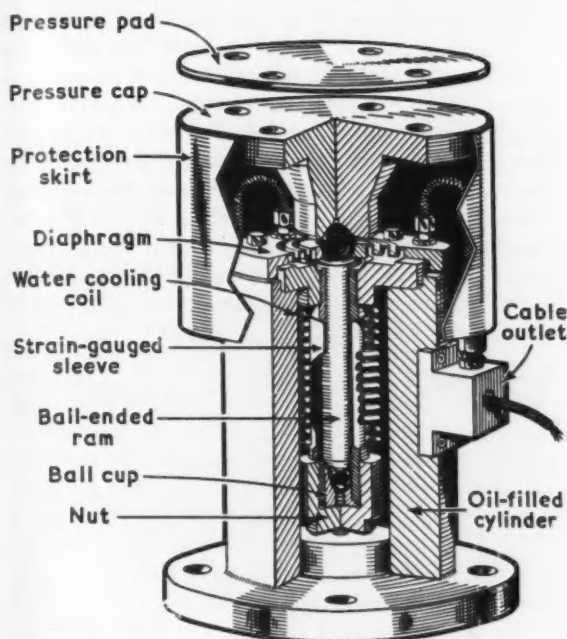
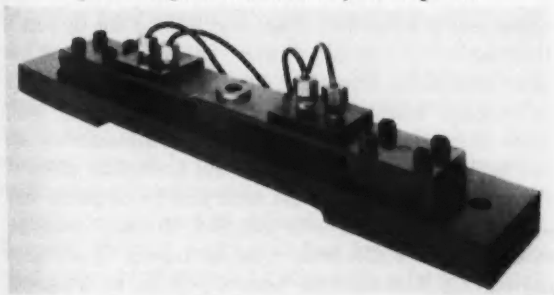


Fig. 13 Interior of the precision load-cell showing the extended stress path

discussed above, becomes a practical piece of engineering when designed for maximum loads of 100 to 2500 tons. A 100-ton load cell may be derated electrically but unchanged mechanically for load ratings between 100 and 50 tons, when it will give half its rated output. It will then carry a side thrust of about 7 tons. For loads in excess of 200 tons the column-type load-cell becomes the only practical design. The toroidal cell can be designed for loading up to 200 tons, but above this load manufacture is difficult, and the precision design becomes unwieldy. Fig. 15 shows a Davy-United cell of the column type for loads up to 250 tons installed beneath the raw meal silos at the cement works of Messrs. G. & T. Earle Ltd., at their new Caudon plant. These tanks each have an all-up weight of 1000 tons and are one of the largest load-cell weighing installations. A problem in the design of the tanks to accept these cells was to allow for the large wind loads, since the tanks are high above the ground in an exposed position, and to permit differential thermal movement of the tanks and their grillages with respect to the supporting structure. It was solved by building flexible joints at both ends of each cell. This allowed the tank

Fig. 14 Weighbeam, without its protecting cover



to expand and contract when tied rigidly by flexure plates against windage. The largest loadmeter which has been produced to date is shown in Fig. 16. It is designed to measure loads up to 2500 tons in a plate-rolling mill, with overloads up to 5000 tons, without damage. For metallurgical reasons it represents a close approach to a limiting design for the column-type load-cell, since in very large cells it becomes difficult to ensure a sufficiently high yield stress at the centre of the heat treated forging from which the elastic measuring element is machined.

Thermal capacity

The need for the largest possible thermal capacity in a load cell, to ensure as uniform a temperature distribution in the gauging zone of the elastic measuring element as possible, has already been mentioned under *Errors due to e.r.s. gauges* (page 121, Part 1). There is, of course, an upper limit to the mass of metal which can be put into a cell, and for smaller cells, up to 250 tons rating at least, the thermal capacity may be increased by filling the space between the outer casing and the elastic mea-

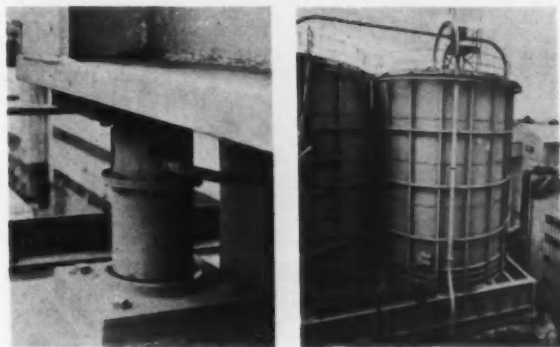


Fig. 15 Left, 250-ton heavy-duty cell in place beneath a silo. Right, Cement-meal silos at Caudon Works

asuring element with a suitable oil. This brings its design problems in sealing the outlet gland, but they may be overcome by good design, and the freedom from zero drift which the oil filling brings is well worth the extra effort and trouble in manufacture.

When cells are to operate in areas with high ambient temperatures, or wherever there is a possibility that they may be exposed to radiation from nearby hot bodies, the cells should be water-cooled. Fig. 17 shows a water-cooled toroidal cell for load ratings from 1.5 to 50 tons. An example of the use of water-cooled load-cells is given in Fig. 18, which shows liquid iron being poured into a ladle from a mixer railcar. The ladle is stood in a pit on a weighbridge of 100 tons capacity supported on four precision load-cells, one of which is shown in Fig. 12.

Precision load-cells have inbuilt water-cooling not only to permit accurate working in high-temperature areas, but to keep the elastic measuring element as close as possible to 18°C, to bring down errors due to change in Young's modulus, E , to a minimum. An average value of the temperature coefficient for



Fig 16 2500-ton loadmeter for rolling-mill applications



Fig 17 Type-D water-cooled toroidal load cell



Fig 18 Weighing hot metal with a load-cell weighbridge

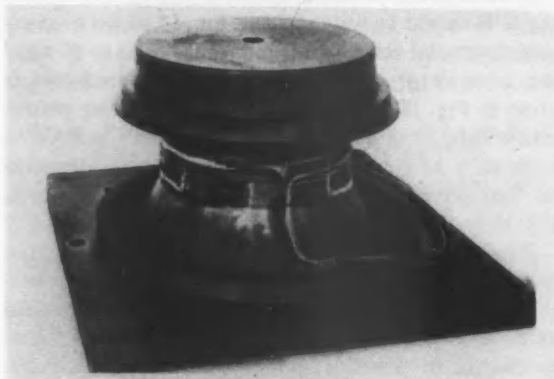


Fig 19 Load cell with thermosetting plastic proofing

E is $0.04\%/^{\circ}\text{C}$, and it will be seen from equation 5 that changes in the elastic modulus will affect the ratio V_m/V_n and hence the calibration constant, c . A precise value of the change in the calibration constant, c , with temperature (which will also be a function of the corresponding dimensional changes in the load cell) has not been determined experimentally, but relatively approximate measurements indicate that the effect of temperature is considerably less than the theoretical value (12). Nonetheless, when measurements are to be made to $\pm 0.05\%$ or better, the error should be eliminated by water cooling.

Water-proofing

One of the greatest difficulties in applying e.r.s.-gauge techniques to stress analysis and to load cells, has been to protect them from contamination by water and water vapour. An e.r.s. gauge must be dry to keep its insulation resistance to the metal to which it is bonded above $100\text{ M}\Omega$. A low insulation-resistance quickly leads to corrosive attack of the gauge wires, and failure. One of the earliest proofing techniques for load cells was to fill the space between the e.r.s. gauges and the outer case with Dijell, a soft wax-like substance, but this was never successful for long on its own. Tannahill (13) subsequently suggested an elaborate proofing, and a rubber bonding suggested by Sims and Morley (14) is also successful until the natural rubber, which may be protected additionally with Neoprene paint, fails. Other forms of rubber proofing have not been successful, for similar reasons. A simpler and far cheaper technique is to encase the gauges in thermosetting plastic as shown in Fig. 19. Gauges have been used in oil and in water for months in experimental stress analysis with proofing of this type without failure.

Installation

No discussion on load-cell engineering would be complete without mention of installation requirements. By far the commonest application of load cells is tank weighing. The tank should be supported on three cells wherever possible. A single suspension is possible for smaller tanks, and Fig. 20 shows a toroidal cell with an axial hole specially designed for this duty. The seating of the suspension rod must be self-aligning in the cell, and the tank itself fitted with stay wires to prevent it swaying in the wind or when struck. A tank may also be supported on two universal joints and one load-cell, or two cells and a rotational pivot. Both systems then approximate to a tank supported on a system of knife edges and a weigh-bar. The objection to the system is that the *entire* calibration must be carried out on site after installation (instead of merely carrying out a check calibration, which is all that is required when using three cells), and errors, particularly non-linearities, are inevitable if the co-ordinates in the horizontal plane of the centre of gravity of the tank and its contents vary as the tank is filled and emptied. In such arrangements, therefore, the tank must be a piece of precision engineering if reasonable accuracy is to be achieved,

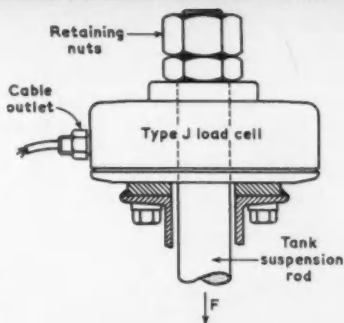


Fig. 20 Type-J toroidal load-cell

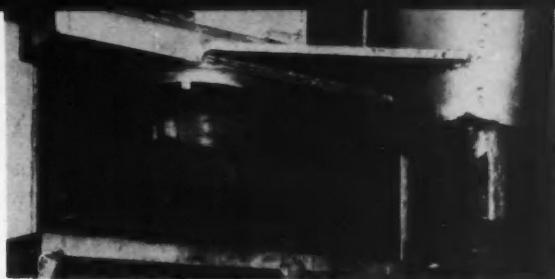


Fig. 21 Toroidal cell, with self-aligning cap, beneath hopper

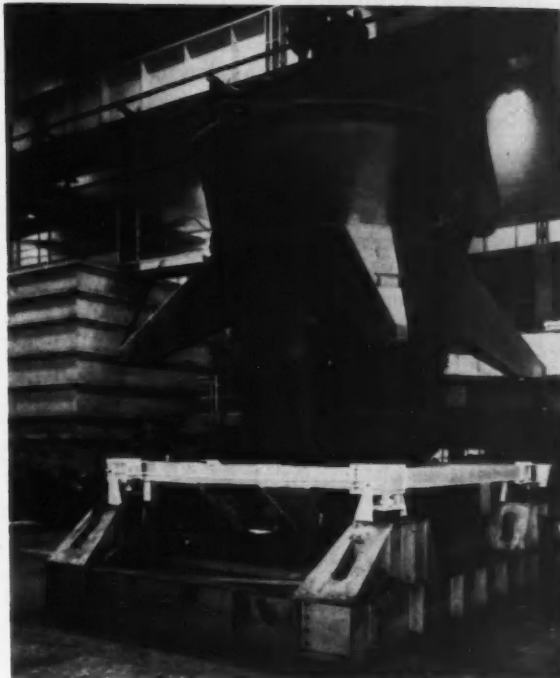


Fig. 22 60-ton scale-car for steelworks, with shock absorbers

and the supports must be specially designed and accurately machined. Generally speaking such a system is not suitable for weighing powders, since the location of the centre of gravity of the loaded tank is then very erratic. Such custom-built arrangements are more costly and usually less accurate than three-point suspension of a tank using standard cells which are batch-produced to close limits and are of high inherent accuracy.

A tank is usually lightly constructed, and will deflect elastically as it is loaded. It may also become warm by exposure to the sun and will change its temperature when filled with cold or hot substances. The tank must, therefore, be able to move freely with respect to the load cells which support it, otherwise large restraints will be set up between the structure and the cells, which will damage them. A three-cell system is preferable since the system is then statically determinate, but four cells, a statically indeterminate system, may be used if carefully installed. The tank should be supported kinematically, i.e. it should be restrained from all movements in the horizontal plane except those due to reversible thermal or elastic displacements. Fig. 21 shows a toroidal load-cell fitted with a standard self-aligning cap arranged as part of such a kinematic suspension. In this arrangement the load cell must be capable of withstanding large side thrusts, since the thermal and elastic distortions must inevitably place heavy horizontal loads on the equipment as the tank moves over the cells. Only when side thrusts are large due to windage or other operating conditions should it be necessary to use tie rods, and then they must be arranged to give adequate support in the horizontal plane without causing measuring inaccuracies.

Shock loading on load cells must always be avoided, since they are rigid, and have a fast response to loading. Most cells are designed to withstand relatively small

overloads, and although toroidal cells as shown in Fig. 11 are capable of 50% overload at least, and usually 100% overload, this may be easily exceeded under conditions of impact loading unless shock absorbers are fitted. Fig. 22 shows a large scale-car in a steelworks, mounted on load cells one of which is shown in Fig. 21. The all-up weight of a full basket is eighty tons, and the unit is designed to weigh sixty tons of scrap to an accuracy better than $\pm 0.3\%$. Shock absorbers are fitted in this case since the loaded basket may be dropped on the cells. The illustration shows the 40-ton-capacity load-cells with their self-aligning caps, mounted beneath a sub-frame on shock absorbers, together with the tie rods to take up the heavy side-loads imposed on the system as the heavy basket is dumped by overhead crane on the frame.

It will be seen from the above discussion on load-cell engineering that these instruments are an attractive solution to all tank-weighing problems, and to certain weighbridge problems. From the mechanical engineer's point of view they have the advantage of being a standard packaged unit of precision weighing, which when properly installed into a fabricated structure will give accurate results immediately. Precise machining and lining up of the structure, and elaborate foundations are all avoided.

To be continued

Long-term reliability is one of the most important considerations in industry, and a radio-active source cannot fail

Nucleonic measurement of level

by **E. W. JONES, B.SC., A.INST.P.**
Isotope Developments Ltd.

Last month we described and illustrated the basic components and their different possible arrangements. Then we began a discussion of factors influencing the choice of source.

For larger industrial vessels, gamma-ray sources are most commonly used. The attenuation of gamma radiation in passing through absorbing materials is given by:

$$I_t/I_0 = \exp(-\mu t)$$

where I_0 is the intensity before absorption, I_t is the intensity after passing through a thickness t cm and μ is the total absorption coefficient. This varies with gamma-ray energy and also with the atomic composition of the absorber, as shown in Fig. 8. However, for energies of about 1 MeV the values of μ are approximately proportional to the density of the absorbers, so that the absorption is, for practical purposes, a function of the weight of material per unit area interposed in the gamma beam.

The intensity received by the detector will also vary with its distance R from the source according to the law $I \propto 1/R^2$.

The most commonly used gamma emitters for level measurement are the radio-isotopes:

1. Cobalt-60: half-life 5.3 years, gamma energies 1.17 and 1.33 MeV;
2. Barium-137 in equilibrium with caesium-137: half-life 33 years, gamma energy 0.66 MeV.

A cobalt-60 source decays by 1% in about 24 days, and a caesium-137 source in about six months, so that regular one-point calibration checks are necessary

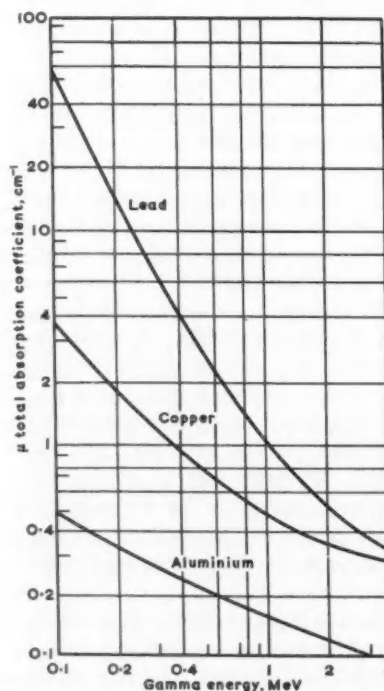
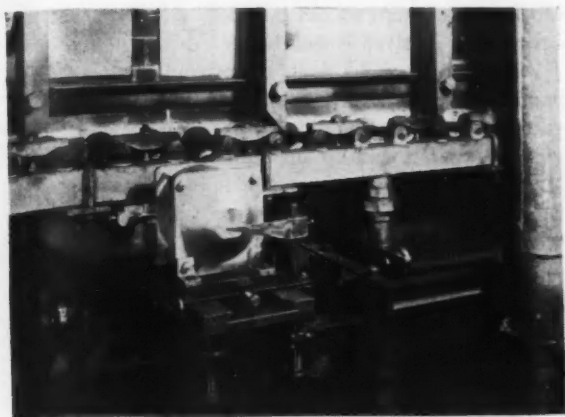


Fig. 8 Variation in total absorption coefficient with energy of gamma radiation



Installation for control of molten glass level in a feeder for bottle manufacture

except for on-off level controllers. The table below shows the source strengths required for on-off control on vessels of various dimensions.

Detector

The radiation detector is usually a halogen-quenched Geiger-Müller tube, since it operates at low voltage, is rugged, has characteristics that are stable over a very long period, and does not require complex circuitry. Its efficiency for beta particles is high, but its efficiency for gamma rays (1-2%) leaves much to be desired. Temperature rating is from - 55 to + 70°C, so that the detector may be operated in the vicinity of many industrial processes without artificial cooling.

For each quantum of radiation detected, the G.-M.-tube circuit delivers a voltage pulse, so the radiation intensity is measured in terms of pulse-rate or 'counts'

Source of strengths in millicuries

DISTANCE (FT)		SOURCE/DETECTOR :								
		2	3	5	8	10	15	20	30	
1 in.	Co-60	1	1	3	10	10	20	40	80	
	Cs-137	2	4	10	30	40	90	160	360	
1½ in.	Co-60	1	2	5	20	20	40	80	160	
	Cs-137	10	20	40	100	160	360	—	—	
2½ in.	Co-60	2	4	10	30	40	80	150	—	
	Cs-137	30	60	160	—	—	—	—	—	
3 in.	Co-60	3	10	20	50	70	—	—	—	
	Cs-137	100	230	—	—	—	—	—	—	
4½ in.	Co-60	20	30	70	180	—	—	—	—	
	Cs-137	—	—	—	—	—	—	—	—	
5½ in.	Co-60	30	50	150	—	—	—	—	—	
	Cs-137	—	—	—	—	—	—	—	—	
6 in.	Co-60	50	100	—	—	—	—	—	—	
	Cs-137	—	—	—	—	—	—	—	—	

N.B.—In each case, radiation through empty container is less than one tolerance at detector (calculated for each source strength and each application).

per second. The maximum rate for halogen-quenched tubes is about 1000-2000 count/s, but they are normally operated at less than 200 count/s.

Electronic unit

The electronic unit therefore usually takes the form of a ratemeter circuit, comprising a pulse-former, diode pump and output valve. The first section ensures that the voltage pulses are of uniform amplitude and duration, the second averages their charge continuously to give a direct voltage proportional to pulse-rate, and the last section amplifies this voltage, or converts it to a current which may be displayed, recorded, or used to operate a relay. Fig. 9 shows a simplified circuit diagram.

Owing to the random nature of radio-active emissions, the fluctuating detector-signal has a standard deviation related to the square root of the number of pulses

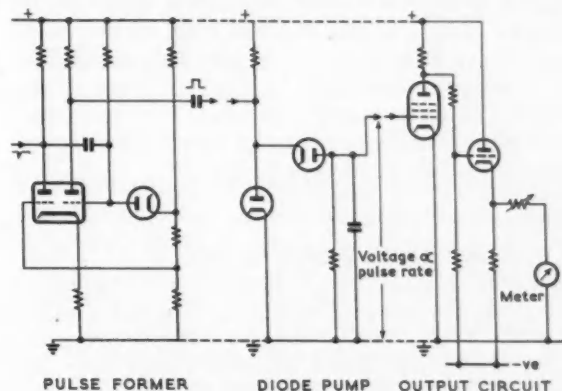


Fig. 9 Simplified circuit of pulse ratemeter

received during the averaging time of the rate-meter. Fluctuation can be made negligible in the output current of the instrument by choosing a sufficiently long averaging time, but this affects the speed of response to sudden level-changes in the vessel.

For simple on-off systems a rate of 30 count/s with an averaging time of 8 s gives a signal fluctuation of about $\pm 7\%$ while the change in signal for control action is usually of the order of 80% or more. The averaging or response time is easily adjusted by changing a capacitor in the circuit.

For more accurate, continuous, level-indication, somewhat higher count-rates are used, and the averaging time is usually of the order of 40-80 s so that statistical fluctuations are not apparent on output-recorder charts.

Reliability

Long-term reliability is one of the most important considerations in the design of industrial indicating and control equipment. So far as the radio-active source is concerned in a nucleonic level-measuring equipment, it can be said for all practical purposes that this cannot fail. There is no way in which the radiation can sud-

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denly cease in the way that a light source might. The radio-activity decays at a known rate, and provided that due allowance is made for this, and the sources are changed at the appropriate intervals, there should be no possibility of failure of the radiation.

The detection equipment depends for reliability on the correct design of ratemeter and amplifier circuits. The Geiger-Müller counter itself, if a well-made halogen-quenched tube, will be at least as reliable as, and probably far more reliable than, any valves in the circuit, and should operate for several years without attention. The circuit must therefore consist of reliable components, and should be arranged so that any deterioration or failure of components will not lead to an incorrect result, but will give some warning. There is one important aspect of nucleonic gauges—that which makes it possible to provide a fail-safe system. No matter what level conditions exist in the vessel, there should always be a small background signal at the detector, due to cosmic rays and other natural radiation. It can be arranged that a relay is kept energized by this background signal, so that any failure of the detector or its associated electronics, leading to complete absence of signal, causes the relay to drop out and thus actuate safety circuits or alarms.

Safety

In considering the question of safety in conjunction with radio-active sources installed in industrial plant, two types of hazard must usually be taken into account.

First, there is the possibility of ingestion or contamination if radio-active materials escape from the source container. This risk can be eliminated if standard radiographic-source capsules are used, as supplied by the Atomic Energy Research Establishment, Harwell, or the Radiochemical Centre, Amersham. These capsules are carefully sealed so that there is no risk of the radio-active material escaping, and the pellet itself is then housed in a light-alloy source-holder and provided with a tag which carries a serial number for identification. The tag may be used for securing the source in its lead housing. It is important to note that radiation from the source holder cannot produce any secondary radio-activity and, in fact, produces no detectable effects in the material within the vessel, in the vessel walls, or in other material subjected to the radiation.

Secondly, there is the hazard due to direct exposure of the body to external gamma radiation. This has been dealt with in special recommendations made by the International Commission on Radiological Protection and endorsed in the Factories (Ionizing Radiations) Special Regulations, which are currently published in the form of a preliminary draft only. The recommendations lay down a maximum permissible level (m.p.l.) for gamma-ray dose to be received in any thirteen-week period by persons who may be exposed to radiations in the course of their work. Assuming a forty-hour working week, the m.p.l. works out at 2.5 mr/h.

Obviously all steps should be taken to ensure that the actual dose received is well below this maximum.

A dose rate of 2.5 mr/h corresponds to about 250 count/s in a typical Geiger-Müller-counter tube for gamma rays from Co-60 or Cs-137. A level detector or indicator can therefore operate satisfactorily at this level, or lower. For this reason it is good practice to design installations so that persons cannot expose themselves to the beam emerging from a source holder at distances less than that of the detector site. In this way the detector itself serves as a monitor of the radiation in the emergent beam. The source holder can be built to give adequate protection in all directions except that in which the beam emerges. Fig. 10 is a schematic plan of an installation showing that, under good installation conditions, operators cannot be exposed to more

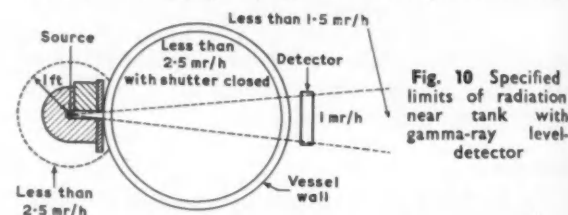


Fig. 10 Specified limits of radiation near tank with gamma-ray level-detector

than the maximum permissible level of radiation, if they remain outside the vessel. It may be necessary from time to time for personnel to enter the vessel for cleaning and maintenance, and the source holder must therefore be provided with a shutter which can cut off the beam and give adequate protection in the forward direction. Such shutters are usually built into large source holders, and operated by a handle fitted with a lock on the rear of the source holder. The lead required to shield the radio-active source may be up to 4in. thick, so the source holders may weigh up to 180 lb. It is standard practice for these source holders to be painted in bright orange or yellow, and to be fitted with a standard warning label indicating that they contain radio-active materials and should not be tampered with.

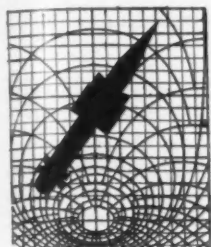
Conclusion

Gamma-ray level-gauges are already regarded as standard equipment for many industrial processes, particularly the measurement of molten glass in the moulded-glass-container industry, and fully automatic control systems are becoming available. In many other processes where the gamma-ray method is being evaluated in comparison with existing systems it would appear that, since complete radiation safety can usually be attained, the main disadvantage is in the relatively high cost of the equipment. Its most important role may therefore be for plant where simplicity of installation procedure and easy accessibility give an appreciable economic saving.

Acknowledgements

Fig. 2, illustrating their Gammawatch, and the photograph in Fig. 4 are reproduced by courtesy of Isotope Developments Ltd., Fig. 6 by courtesy of A. M. Lock & Co., and Fig. 7 by courtesy of Macleans Ltd. The photograph of the installation for control of molten glass level is reproduced by courtesy of Rockward Glass and Isotope Developments Ltd.

End



PART C

Fluid flow through an opening is proportional to the square root of pressure drop, but the effects of non-linearity are not too serious with electrically signalled control valves

Hydraulic servos

by P. D. BOYER, B.Sc.

English Electric Aviation Ltd.

In February we considered the missile applications of electro-hydraulic systems and stated the basic properties of the hydraulic servo-mechanisms used. Last month we continued from Part 1 our account of components, and gave a general treatment of all currently used relays, motors and pilot-stage transducers. Below, we go on with our study of components.

The servo-valve

The servo-valve—that is, the combination of valve and torque motor—is the main power amplifier in the system and the key to most of its control problems.

Taken over Western missiles as a whole, the output end is almost always a spool valve, a form which is well tried and in some ways ideal. Indeed, in terms of numbers made and attainable performance it must count as the most successful. Other forms are in use however, as Fig. 4 shows. The use of an intermediate hydraulic preamplifier, of the flapper and nozzle type, between torque motor and main spool is now predominant in the U.S., although not in this country. It is perhaps not yet truly superior in all respects to the alternatives. From the aspects of size, weight, simplicity, ruggedness and ease of energization it shows a marked advantage. But it still has a susceptibility to null shift (giving the equivalent of d.c. drift), and to vibration, and a rather high neutral leakage. These problems are difficult to overcome but great advances have recently been made. Meanwhile, if careful examination of the system's suitability in any given case is still desirable, its adoption will nevertheless usually be found practicable. It is the only type in large-scale production in the United States.

What constitutes the transfer function of servo-valves is an often confused question. This largely comes about

because the true t.f. is difficult to measure. Frequently, the response quoted in technical sales publications is in fact the velocity of an unloaded oil motor or actuator versus the input signal to the valve. This makes for a conservative claim but one liable to differ from one test rig to another: and conservatism in estimates of natural frequency does not necessarily promote servo stability. The true response is bound to be modified by friction and inertia in the oil-motor, and if the servo-valve has a high natural frequency, compressibility, oil inertia and organ-pipe effects may all come into the picture (2, 3).

Now these effects are not inherent in the valve but are part of the transfer function of the piping installation and the actuator. The true no-load flow response of a servo-valve is Q_m/i . The response of x/i , taken with the valve working but short-circuited with a very short pipe, is as near as one can get to this function with present-day transducers.

If the flow-displacement relation is linear, with slope $(\partial Q_m/\partial x)_{P_m} = \bar{k}$, then the amplitude ratio x/i must of course be multiplied by \bar{k} to obtain Q_m/i . If the Q_m-x curve is non-linear the problem takes on a completely different aspect and the response is best considered in two parts, one being the linear part x/i . The other, Q_m/x , is best treated by the describing-function method, (4). However, unless such a characteristic is definitely a requirement, such non-linearity is nowadays largely avoidable.

The square-root law

The no-load flow response discussed above is applicable when there is negligible pressure-drop across the load. This is a rather special case, however.

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Fig. 4a Dowty-Moog servo-valve series 22. Maximum flows up to 10 gal/min. Working pressures up to 4000 lb/in²



The available pressure drop from the supply line at P_s to the exhaust line at P_e is divided between motor pressure drop, P_m , and valve drop, $P_s - P_e - P_m$. The drop across any given active orifice in the valve is $\frac{1}{2}(P_s - P_e - P_m)$. It is fairly well known that hydraulic valves are governed by the square-root law of flow versus pressure drop, in this case taking the form:

$$Q_m = C_d w x \left(\frac{2}{\rho} \right) \left\{ \frac{1}{2}(P_s - P_e - P_m) \right\}^{\frac{1}{2}} \quad (35)$$

How is this effect to be taken care of?

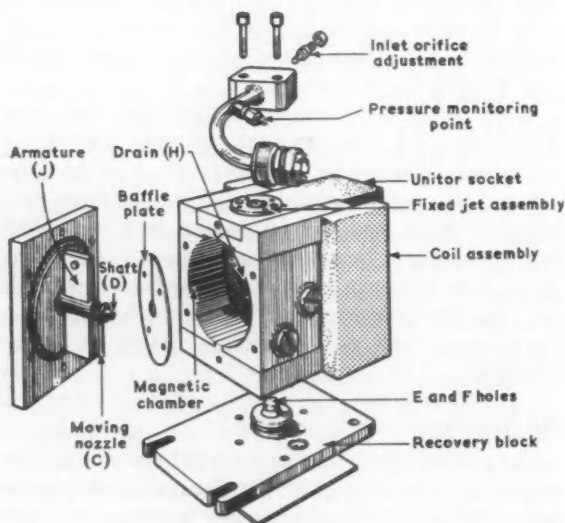
One method, in effect the small-perturbation method (5), is to consider the response to a small sinusoidal variation in i . The current signal is thus thought of as made up of a constant d.c. signal \bar{i} and a small a.c. signal \tilde{i} . The standard relation of partial differentiation theory, viz.

$$dQ_m = (\partial Q_m / \partial P_m)_x dP_m + (\partial Q_m / \partial x)_{P_m} dx \quad (36)$$

is applied at a particular working point (Q_m, P_m, x) for which the derivatives

$$(\partial Q_m / \partial P_m)_x = \sigma \quad \text{and} \quad (\partial Q_m / \partial x)_{P_m} = \bar{k} \quad (\text{say}) \quad (37)$$

Fig. 4b Ferranti jet valve used in Bloodhound. Askania-type nozzle directs jet into holes E or F. These communicate with jack. Velocity head of fluid is recovered as pressure head to actuate jack



are known. If the resultant variations in Q_m , P_m , and x are q_m , p_m , and \bar{x} , then from eq. 36

$$q_m = \sigma p_m + \bar{k} \bar{x} \quad (38)$$

This must be combined with the equations for valve response:

$$\bar{x} / \bar{i} = x / i = F(j\omega) \quad \text{say,} \quad (39)$$

the actuator torque equation

$$p_m D_m = M \psi''_0 + B \psi'_0 + C_1 \psi_0 \quad (40)$$

and the actuator flow equation

$$q_m = D_m \psi'_0 + (V/2\bar{K}) p'_m \quad (41)$$

For an explanation of the second term of the r.h.s., if needed, see the passage following, on the subject of actuators. ψ_0 is the resultant small variation in θ_0 . These equations give

$$D_m \psi'_0 + (V/2\bar{K} D_m)(M \psi'''_0 + B \psi''_0 + C_1 \psi'_0) = (\sigma/D_m)(M \psi''_0 + B \psi'_0 + C_1 \psi_0) + \bar{k} F(j\omega) \bar{i} \quad (42)$$

or

$$\begin{aligned} \{ (VM/2\bar{K} D_m) p^3 + [(VB/2\bar{K} D_m) - (\sigma M/D_m)] p^2 + \\ [D_m + (VC_1/2\bar{K} D_m) - (\sigma B/D_m)] p - (\sigma C_1/D_m) \} \psi_0 \\ = \bar{i} \bar{k} F(j\omega) \end{aligned} \quad (43)$$

There is of course a specific solution for each working

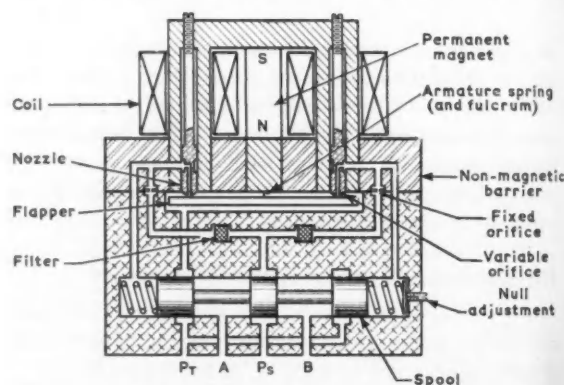


Fig. 4c Vickers Spacemaster servo-valve. Maximum flows up to 12 gal/min at 1000 lb/in². Working pressures up to 3000 lb/in². Weight 8½ oz

point. Such complication could usually be avoided however, as will be shown.

Magnitude of the pressure non-linearity

Hydraulic servos are often spoken of as very non-linear precisely because of this square-root law of flow versus pressure and its supposedly inevitable effects. The latter are real enough in valves with a *mechanical* input of high reverse stiffness, that is, when the motion of the valve driver is virtually irresistible so far as its working loads are concerned. But in electrically-signalled control valves this is not often the case, and the effects need not be as bad as is sometime assumed.

Fig. 5 shows a plot of flow versus pressure for a four-way servo-valve at different openings, to which the square-root law—as is usual—applies very accurately. On such a graph a sinusoidal output motion is represented by an ellipse, provided friction and other non-linear loads are ignored. In the present case sup-

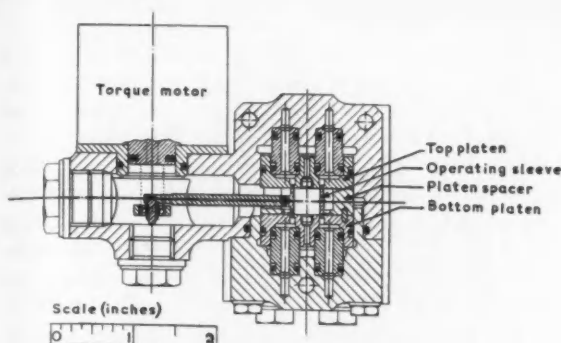


Fig. 4d(i) General arrangement of Fairey servo-valve

pose that we have a flow equation (as discussed in detail later under *Hydraulic actuators*) as follows:

$$Q_m = D_m \theta'_0 + (V/2K) P'_m \quad (44)$$

and a torque equation:

$$P_m D_m = M \theta''_0 + B \theta'_0 + C_1 \theta_0 \quad (45)$$

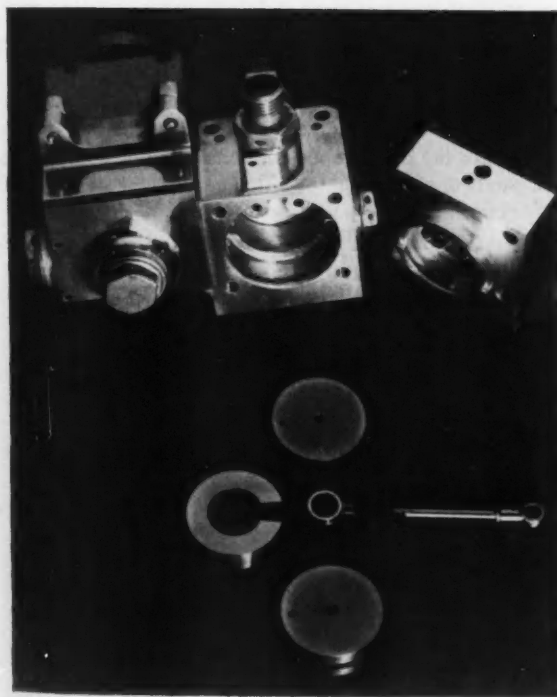
If $\theta_0 = \bar{\theta} \sin \omega t$ (46)

then Q_m and P_m are both of the form $X \cos \omega t + Y \sin \omega t$, i.e., sinusoidal in form and of the same frequency, so that the Q_m - P_m curve is an ellipse.

A broad ellipse implies a high power output and greater efficiency than a narrow one, but it is usually necessary in high-performance servos to accept some limitations here, for the sake of the greater linearity which, as will be seen, is conferred by the narrow ellipse.

Fig. 6 shows the ideal flow calibration curve for the valve of Fig. 5 (full line), taken with a constant pres-

Fig. 4d(ii) Dismantled Fairey servo-valve. Maximum flow up to 1.8 gal/min. Working pressure up to 4000 lb/in²



sure drop across the ports of $P_s/2$, P_e being assumed zero like P_m . Under load, the working relationship between flow and displacement is shown by the dotted lines, which were derived from the intersections in Fig. 5.*

This form of graph illustrates the non-linearity in the way most readily appreciated and shows that the effect is not very marked as long as $P_{m\max}/P_s$ does not exceed $1/5$. Coombes (6), has suggested, by reference to

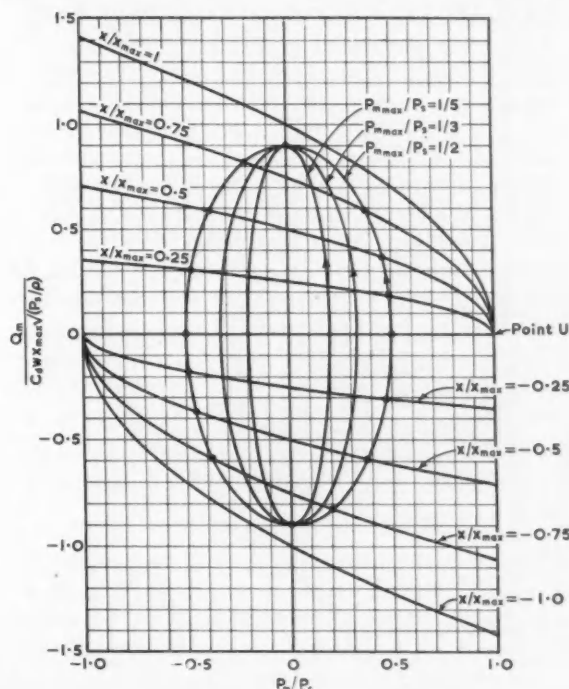


Fig. 5 Flow plotted against jack pressure-drop for a four-way servo-valve at various openings. Superimposed on the graph are ellipses representing sinusoidal motion of the jack against various inertias

the corresponding valve position wave-forms, that $P_{m\max}/P_s$ can be allowed to reach $1/2$ without noticeable effect.

These criteria can only apply to sinusoidal signals, of course. During a step response, the working point on Fig. 5 moves out to the point U and then (initially) along the appropriate line of constant opening (x_{\max} if the change in input exceeds the saturation error) before spiralling in towards the point of equilibrium. A solution for the unsaturated case is given by Turnbull in (7). A suitable introduction to the phase plane techniques employed in that paper is to be found in (8). Treatments such as these, while valuable, are extremely cumbersome and expensive to apply.

A rule-of-thumb limiting $P_{m\max}/P_s$ in the sinusoidal

* An interesting aspect of these curves is that they demonstrate a hysteresis, which imparts energy to the spool. This can result in oscillations (2) although, except in very-long-stem valves, these do not seem to have troubled many users. The effect of friction in the actuator is readily embodied. It takes the form of a direct lateral displacement of the halves of the ellipse in Fig. 5, the upper half to the right, the lower half to the left. Transposition of the revised points into the form of Fig. 6 shows surprisingly little influence on the latter.

case to about $\frac{1}{3}$ is now quite widely used. In the g.w. industry's early years such wide variations as 1/10 and $\frac{1}{3}$ were common and some wing and fin servos are still designed, of necessity, to permit $P_{m\max} = P_s$. The ratio governs the jack design, e.g., for a rectilinear ram

$AP_{m\max}$ = maximum specified load
and A should be decided accordingly.

Thus, given a suitable jack design, the square-root law promotes only mild non-linearity under normal working conditions and when it does offend, actuator force or torque saturation is already imminent. Yet even this degree of non-linearity is easily avoided since the variation of flow with pressure does not, or need not, fully materialize in most systems. The output stage of the vast majority of servo-valves is a spool valve and this normally develops a force due to flow reaction (9, 10, 11). The flow force is usually equivalent to a fairly linear spring with stiffness proportional to the orifice pressure-drop, $\frac{1}{2}(P_s - P_e - P_m)$ or P_v . Indirectly this has the effect of reducing the pressure gain variation to a very marked degree, as shown below.

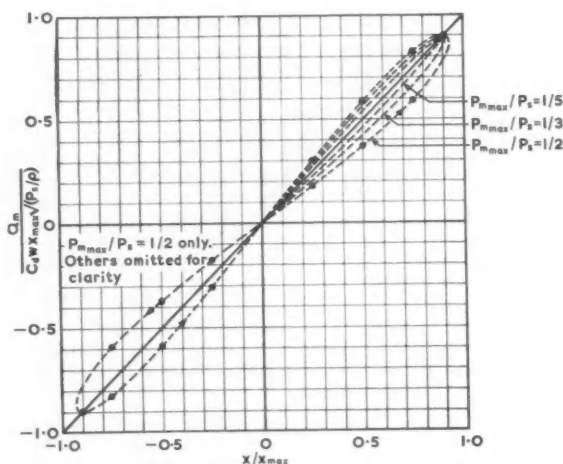


Fig. 6 Magnitude of non-linearity from the pressure load effects in servo-valves where $Q_m \propto \sqrt{P_v}$ at constant signal current. This occurs, for example, when the hydrodynamic reactions ('Bernoulli' forces) are eliminated

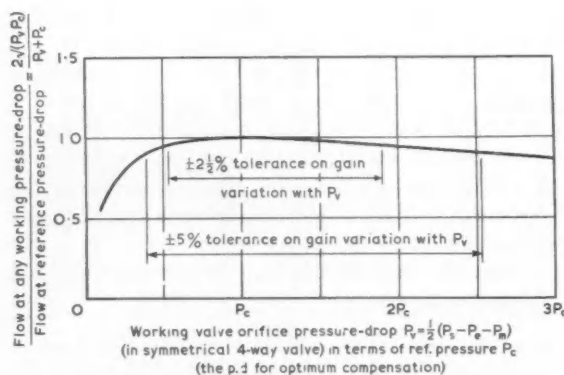


Fig. 7 Variation of flow with valve pressure-drop, in valve with simple compensation

Pressure compensation

The majority of servo-valves are driven by a motor or first stage giving a force output on the spool linear with current and displacement. Fig. 3 shows typical torque, current, displacement curves for a torque motor. Superimposed on it are the load lines corresponding to the flow reaction forces in a four-way valve at various operating pressures. At one particular pressure, when the flow-force stiffness is half the total valve-and-torque motor stiffness, inclusive of any mechanical spring, full pressure compensation is achieved.* This, briefly, is because at any given input current the tendency to rising flow due to rising pressure is cancelled by the fall in displacement due to rising load line. Over the full pressure range the resulting variation in gain is shown in Fig. 7.

P_e is the optimum working pressure for any given electromechanical stiffness. It is clear that the latitude in choice of working pressure is large and that, if anything, it would be better to make the working mean value of P_v higher than the optimum. However, if P_s is already fixed and found to give a 'flow stiffness' less than the stiffness of the torque motor, the non-linearity at working pressure drops below the optimum is not so bad as to justify lowering the torque-motor stiffness and natural frequency.

With such pressure compensation the flow equation is

$$Q_m \approx \alpha F(j\omega) \quad (47)$$

and this, together with eqs. 44 and 45 gives

$$\theta_o = \frac{\alpha F(j\omega)}{i \left[\frac{VM}{2\bar{K}D_m} p^2 + \frac{B}{M} p + \left(\frac{C_1}{M} + \frac{2\bar{K}D_m^2}{VM} \right) \right]} \quad (48)$$

and the system is linear even for quite large excursions.

The flow reaction forces are large enough to limit most linear high-pressure single-stage servo-valves to about 2 or 3 gal/min using the available torque motors. Even two-stage valves become difficult to drive above 10 gal/min without quite powerful first stages. If high flows are the most important consideration then several methods are available for reducing flow forces. Lee and Blackburn's method is very effective (9) but expensive and difficult to embody, and it leaves some residual spring stiffness near the origin as an unwelcome force non-linearity. Its most successful production forms are probably to be found in the Midwestern, Oilgear and Hobson servo-valves.

Lee's arrangement in (24) is applicable to a valve type which, despite early promise, does not yet seem to have met with much success in production. Turnbull's method (12) while inexpensive and permitting a useful stiffening of the spool, accepts not only the sacrifice of some flow non-linearity but also a considerable and awkward spring-stiffness variation. Servo-valves of the R.A.E./R.T.V.1 type (Fig. 8a) give considerable reduction in force at large flows but also leave a residual force non-linearity near the origin. For these reasons,

*That is, $\partial Q_m / \partial P_v$ is zero.

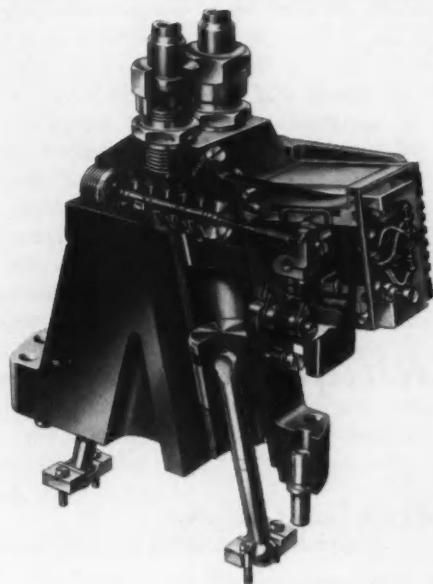
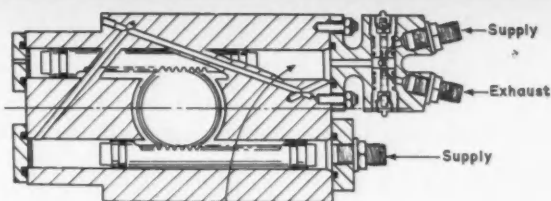


Fig. 8a Hobson servo-unit Type 139. Working pressures 1000-4000 lb/in². Torque output up to 15 lb ft



Maximum pressure in actuator	3000 lb/in ²
End area of cylindrical ram	0.25 in ²
Crank radius	0.75 in
Displacement per radian on drive side	2 X 0.75 X 0.25 = 0.375 in ³
Displacement per radian on pre-load side	0.75 X 0.25 = 0.1875 in ³
Actuator travel	± 60°
Mean trapped volume on drive side	7 cm ³

Fig. 8b Elliott test actuator and B603R servo-valve. Three- or four-way, ± 60°. Maximum pressure 3000 lb/in². Stalling torque 560 lb in. Typical performance figures for a closed-loop system using the components shown: supply pressure 1000 lb/in², exhaust pressure 10-80 lb/in², control pressure for equilibrium 500 lb/in², control pressure to move actuator against Coulomb friction (with perceptible dither) 575-425 lb/in², stall torque 187 lb/in², actuator pick-off excitation 36 V (r.m.s.) 2400 c/s, maximum valve flow 5 in³/s, maximum angular shaft rate 13 rad/s, neutral leakage 2 cm³/s, load 32 lb in², velocity constant with shaping 300 ditto without shaping 150-200, low-frequency phase lag per c/s 1.2°, rest accuracy better than 1', minimum amplitude for sinusoidal following < 4' observed

Fig. 8c Vickers hydraulic motor. Weights down to 2.6 lb, maximum speeds up to 9000 rev/min, working pressures up to 4500 lb/in²



during the development of many valves, flow-force reduction has been abandoned at an early stage to the great advantage of both performance and analysis.

Power saturation

Reverting for a moment to the load ellipse, Fig. 5, it can be seen that saturation sets in when the ellipse touches the curve corresponding to maximum valve opening. It is in fact power ($D_m P_m \theta'$) saturation. In limiting cases this becomes velocity or acceleration saturation. A treatment of the general case is given in (13), taking account of oil compressibility.

Hydraulic actuators

All conventional types are to be found in missiles. Some examples are shown in Fig. 8. The rotary patterns have the advantage of inherent backlash elimination. All except the vane motor suffer from marked Coulomb friction. Usually relatively little viscous friction is present. The Coulomb friction is most severe when Neoprene seals are fitted, but, rather surprisingly, the stiction and dynamic friction are not usually very different. A typical value for the pressure drop necessary to overcome friction would be 30% P_s . At best this can be reduced to 10% P_s .

Since oil is compressible, the oil and actuator load form a mass and spring system. The stiffness of the oil in each cylinder is derived from the relation for the bulk modulus of a fluid.

$$\bar{K} = - \frac{V \cdot dP}{dV} \quad (49)$$

and the stiffness equation for the actuator

$$\frac{dF}{dl} = \frac{A \cdot dP}{dl} = \frac{A^2 \cdot dP}{dV} \text{ OR } \frac{dT}{d\theta} = \frac{AR \cdot dP}{d\theta} = \frac{A^2 \cdot R^2 \cdot dP}{dV} \quad (50)$$

As an example, if there is no other mechanical spring involved ($C_1 = 0$), the undamped natural circular frequency of an equal-sided rotary actuator, when in its central position, is given by

$$\Omega_n = \left(\frac{\text{Stiffness}}{\text{Inertia}} \right)^{\frac{1}{2}} = \left(\frac{2\bar{K}A^2R^2}{(AR\theta_{\max} + v)M} \right)^{\frac{1}{2}} \quad (51)$$

It is a primary design point to minimize the parasitic interconnexion volume v , and so we have

$$\Omega_n \propto (AR)^{\frac{1}{2}}, \text{ i.e. } \propto (D_m)^{\frac{1}{2}}$$

Given that $v = 0$ the natural frequency of the same actuator in the general positional case is

$$\Omega_n = \left(\frac{2\bar{K}AR^2}{M} \right)^{\frac{1}{2}} \left[\frac{\theta_{\max}}{(\theta^2_{\max} - \theta^2)} \right]^{\frac{1}{2}} \quad (52)$$

Variable hydraulic stiffness is seen to be another non-linearity and is significant at large look-out angles or fin displacements.

At low frequencies the change in oil volume (dV) and density due to compressibility do not achieve very significant values in hydraulic servos. However, the rate of change at high frequencies certainly does. From equation 49 comes

$$\frac{dV}{dt} = - \frac{V}{\bar{K}} \frac{dP}{dt} \quad (53)$$

Oil entering an actuator cylinder head must top up the volume lost in compression in addition to displacing the piston. Thus, equating flow rates

$$Q_m = (\text{Piston area} \times \text{piston velocity}) + \frac{V}{\bar{K}} \cdot \frac{dP}{dt} \quad (54)$$

To be continued

The authors see a trend toward digital electronics, and describe an integration-based method which can be used for synthesis of non-linear functions

Digital and hybrid simulation techniques

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INVESTIGATION BY SIMULATION, USING COMPUTERS AND associated equipment, is now a well established practice, accepted as essential in various fields of science and engineering.

Unfortunately the electronic analogue computer, although it is in many ways ideal for simulation—and almost the only means available to-day for problems with fast response in real time—has some serious limitations as an advanced tool for complex problems with non-linearities, and there has been a trend towards the introduction of digital circuit techniques into simulation. The fully digital simulator known as the d.d.a. (i.e. digital differential analyser) has received some publicity already, but it is felt that some attention should also be given to the possibilities of using hybrid circuit techniques, part-digital, part-analogue. It is suggested that a hybrid system may have application as this could offer moderate accuracy, high speed, performance with simple equipment in non-linear operations, etc., where the analogue computer is not completely satisfactory.

Very relevant to this subject is the technique of generating functions using the operation of integration as a basis. This, and other considerations to be discussed, point to the need for complete installations or auxiliary computers based on d.d.a. or hybrid techniques. The principles involved are not new, but their application in simulation work has been slow in developing, and the potentialities require to be emphasized.

Evolution of digital simulation techniques

Practical and economic considerations, together with those of availability, in many cases prevent the actual physical system being used in the solution of problems.

It is evident that very great advantages lie with any

computing system which, in effect, provides a mathematical model available for continuous operation, as with analogue operation. Analogue computers, however, have been limited in accuracy and scope of problem because of the use of analogue components. Thus, digital arithmetic computers have had application not only to problems peculiarly suited to them, but also to those in the analogue realm for which the technique of analogue operation has been insufficiently advanced as yet.

Broadly speaking, the limitations are with regard to accuracy, non-linear operations, general problem complexity, dynamic range, and reliability. With major improvements, the field of application lost to the digital arithmetic machine may be regained, and a renewed demand found for computers operating analogue-wise.

Possibly the greatest disadvantage of existing forms of electronic analogue computer is the inability to integrate and differentiate with respect to a variable other than time. This restriction severely limits the range of non-linear functions which may be obtained with an economic arrangement of computing units, and prevents the simulation of partial derivative problems.

One of the main advantages of the analogue computer compared with the digital computer is its faster operation, permitting simulation in real time. For this reason alone there is a definite field of application for the electronic analogue computer, despite its limitations in accuracy, alongside the digital computer. Any means of increasing its capabilities, such as those described, would obviously make it an even more attractive companion.

The employment of digital units in an analogue system has been evolving gradually, the resulting computer being termed a digital differential analyser (d.d.a.). This

technique would appear to get over the shortcomings of the pure analogue computer, and at last there is the prospect of a computer which will adequately cover the full field of application. There should be no need now to appeal for assistance from an arithmetic machine, except when a special problem arises which justifies its use.

In analogue operation the d.d.a. represents the opposite extreme to the pure analogue computer, in that only units of a digital kind are used. Hybrid systems are possible, however, still preserving the analogue mode of operation, but employing both pure analogue and digital units in association. Details of possible hybrid systems are ill-defined at present compared with those of d.d.a. technique, and, although greater attention is paid to the latter in this paper, it is not intended to give the impression that hybrid systems are any less important.

Additional features demanded by increasing complexity

The additional computing features should be considered which have to be introduced as a result of increasing problem complexity. The need to retain an analogue mode of operation will be borne in mind throughout.

Taking linear equations as a starting point, additional facilities are required for:

- Simple non-linearities such as limits, dead zones, and hysteresis
- Transport delay
- Multiplication of two or more variables
- Axes transformations
- Generation of analytic or arbitrary non-linear functions of a single variable
- Functions of several variables
- Partial derivative equations

Arising out of the limitations of present analogue-mode technique, various devices are used: non-linear equations are 'linearized' at the expense of limiting validity to small variations; partial derivative equations are treated by 'finite difference' methods but uneconomic

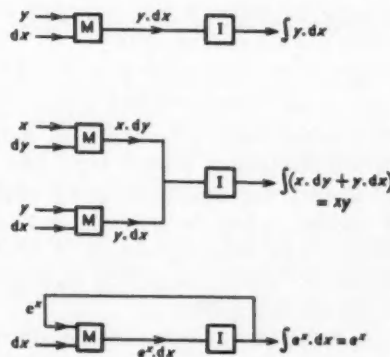


Fig. 1 Examples of function synthesis by integration—generalized method

computing capacity is involved except for simple approximations.

There is a definite need to face the problems of economic non-linear simulation and direct simulation of partial derivative equations. This is particularly true in

view of the increasing volume of work on spatial distribution problems, related to heat flow etc. in atomic energy and industrial systems, and the increased emphasis on non-linearities in general.

Facilities for the above operations automatically provide for axes transformations, vector operations and complex variables.

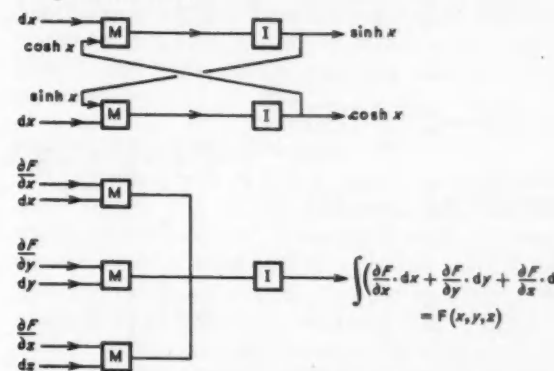


Fig. 2 Examples of function synthesis by integration—generalized method

The computing operations discussed have no basic arithmetic feature in common to demand the use of an arithmetic computer and there is every incentive to continue the development of computers operating in the analogue mode until all these features can be incorporated. As will be seen, the d.d.a. already offers these facilities.

Conventional analogue methods of non-linear-function generation

It will be interesting to consider first the limited means available for extending conventional analogue computers to complex problems with numerous non-linear features.

The basic computer, consisting of feedback amplifiers with resistive and capacitive components, can of course only be used for linear problems, so non-linear problems involve the addition of special non-linear units.

Limits and dead-zones can be introduced easily in an economic fashion.

For general function generation there are the alternatives of a slow unit using an electro-mechanical servo and a shaped potentiometer, or fast devices, e.g. using semiconductor diode and resistor sections. Such units have proved reasonably successful, but they have the disadvantage of requiring to be set up manually for each particular function. While this may be inevitable for an arbitrary function—unless it can be stored—it is unreasonable for a simple analytic function.

The generation of a function of two or more variables is extremely difficult, and involves a considerable number of computing units.

Multiplication of two variables is commonly required. There are many ways of doing this, and only a few examples will be mentioned. First there is the relatively slow servo-multiplier, using one or more potentiometers driven by an electro-mechanical servo. Then there is

the high-speed multiplier, using semiconductor diode and resistor sections operating on the well known 'quarter-squares' principle. A more attractive scheme uses a central triangular-wave generator to supply all points in the simulation where multiplication is required. Broadly speaking, only a number of semiconductor

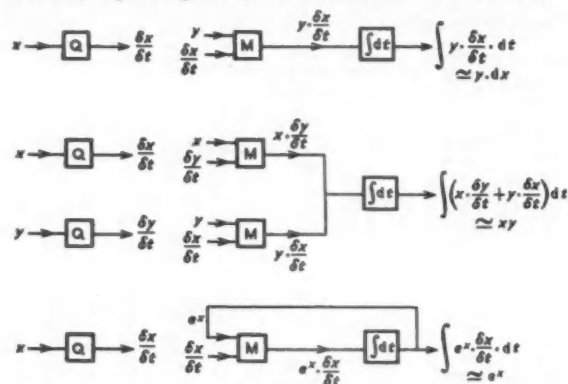


Fig. 3 Examples of function synthesis—time integration method

diodes and resistors is required at each point, with some extra amplifiers. The system can be extended economically.

Existing non-linear computing units generally comprise a number of computing amplifiers in addition to various non-linear networks. For this reason, it is difficult to achieve in these units the accuracy obtainable with the linear computing units. Also, the overall accuracy of a computer employing non-linear units is

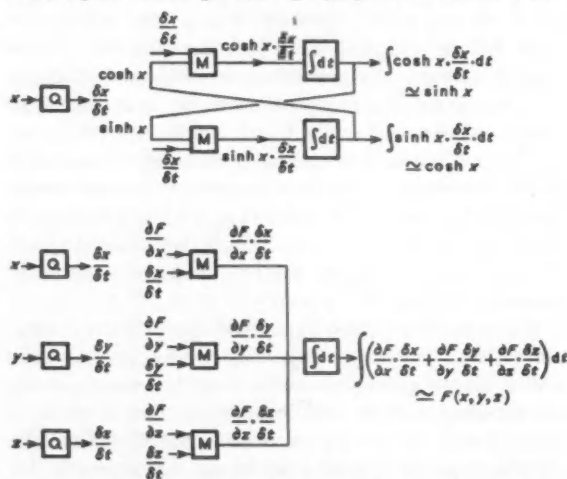


Fig. 4 Examples of function synthesis—time integration method

very much more dependent on the magnitude of the signals employed, and great care must be taken to ensure that full scale values are obtained where possible.

General limitations of analogue computers applied to complex problems

As well as the lack of comprehensive integrated facilities for non-linear function generation apparent in the above, there are the following aspects of performance

which offer little prospect of improvement with a pure analogue computing equipment:

Accuracy and frequency response, especially of the non-linear units. In contrast to a digital system, accuracy falls with increasing computer capacity

Drift performance

Dynamic range. 60 dB is quite good, but 80 to 120 dB is required, for example, in nuclear problems

Reliability. A variation in component performance may be sufficient to give unacceptable results, whereas a component failure would usually be necessary with digital equipment

There is the disadvantage also that analogue computers cannot be operated in conjunction with digital computers, or the digital pick-off devices in data handling and process control, without appropriate converters.

General synthesis of non-linear functions by integration

Given a means of integrating with respect to any variable—not just time—a wide range of mathematical relationships can be simulated. The basic problem is to generate the function $\int y \cdot dx$ which involves multiplication of y and dx followed by integration, and it is interesting to note that this combined operation is the basis of the d.d.a. computer.

Fig. 1 illustrates the generation of the $\int y \cdot dx$ using a multiplier M and a special integrator I . It goes on to show how this operation may be used to generate the product xy and the function e^x .

Two further examples are shown in Fig. 2. The generation of $\sinh x$ or $\cosh x$ is seen to involve generation of both simultaneously, using feedback connexions to the inputs of the multipliers. A method of obtaining a function of three variables x , y , and z from its partial derivatives is shown in the lower example.

A special integrator, such as the digital type used in a d.d.a. computer has been assumed in the above since an electronic pure-analogue integrator can only integrate with respect to time. In Figs 3–5, y has been taken as a pure analogue voltage and dx/dt as a positive—or negative pulse in a hybrid digital-analogue system. Fig. 5 shows the sliced output wave-form for $y \cdot dx/dt$ which is used as the input to a pure analogue

integrator producing the time integral $\int y \cdot dx/dt \cdot dt$.

In a d.d.a. integrator, operation is similar in principle, as will be seen in Fig. 6 where the basic modulator is also shown for comparison. Input pulses δy and δx are obtained as outputs from other integrators and δy in integrated digitally to give y which is stored in a Y register. y and δx are multiplied together, and the product $y \cdot \delta x$ integrated simply by adding $+y$ or $-y$ into an R register successively according to whether δx is positive or negative.

A multiplier consisting of a modulator switched by an incoming pulse is most attractive for function generation. Considerable numbers of these units would be used and accordingly the simplicity of design possible becomes a most important feature.

The use of digital integrators as well as pulse modulators leads to the fully digital d.d.a. system which is

essential for high-accuracy working. If, however, lower-accuracy function generation can be tolerated, the pulse-type modulator could be associated with a pure analogue integrator in a hybrid digital-analogue system.

D.D.A. applied to complex problems

It seems appropriate now to discuss the d.d.a. in relation to the various limitations of analogue computers listed earlier.

Simple means of multiplication seems to be the answer to non-linear problems and partial derivatives, and, since this is a basic d.d.a. operation, the d.d.a.

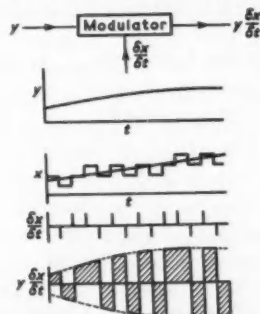


Fig. 5 Operation of pulse modulator

is suited to complex problems without special arrangements.

For the same maximum frequency, accuracy may not be better than with a pure analogue system; but there is the added flexibility, not possible with the latter, of being able to interchange accuracy and speed to suit the problem.

Dynamic range is limited only by register capacity which could be varied to suit the problem.

Transistors are ideal for the on-off digital technique employed, and the combination of these should result in increased reliability and other features important in large computing installations. Either manual or automatic setting-up of the problem should be possible by electronic means from a central point. Greater compactness also may be expected, and accuracy should be unimpaired with increasing size.

Digital pick-off devices in data-handling and process control should combine readily with a d.d.a. system, and easy connexion to a digital arithmetic computer should be possible without special converters.

The increased reliability of a transistorized d.d.a. would be invaluable in process control, since a computer break-down might seriously affect the operation of an expensive plant.

These considerations suggest that the d.d.a. technique is indeed the answer to many of the problems arising in developing comprehensive computing systems operating in the analogue mode.

Alternatively: hybrid digital-analogue technique

It has been shown that integration of products of the form $y \cdot \delta x$ can be the basis of an integrated approach to non-linear function generation. Moderately accurate multiplication by a simple switching method is possible with y retained in analogue form and δx expressed

digitally as, say, ± 1 . Also, a pure analogue integrator can be used to integrate the product $y \cdot \delta x$ as well as general integration with reasonable accuracy. Thus a hybrid digital-analogue technique offers the possibility of extending analogue computers to complex problems by adding switch-type multipliers, and analogue-digital converters as required, to the pure analogue integrators. The field of application is limited by the accuracy obtainable, but there is some attraction in the possibilities of high speed of operation and reduced cost of equipment.

Auxiliary d.d.a. or hybrid computer

A completely new installation based on d.d.a. technique should offer all the performance and facilities which might be desired in simulation work. However, the possibility of using an auxiliary d.d.a. computer in association with an existing analogue or digital computer, or both, seems very attractive.

Used with an analogue computer, the auxiliary d.d.a. could provide, for the first time, non-linear function generation with accuracy as good as that of the linear analogue units. In contrast to a complete serial d.d.a. installation, the time-sharing d.d.a. integrator would not require to serve the linear system, and this would result in higher speed of d.d.a. operation. Apart from non-linear function generation, the auxiliary d.d.a. computer could provide analogue-digital converters, digital-analogue converters and other desirable facilities for the complete installation.

Where both analogue and digital (arithmetic) computers are available, the auxiliary d.d.a. offers a means of operating all three together. The linear operations could be done on the analogue computer, enhanced-accuracy linear operations and function generation on the d.d.a., and special function generation or programme storage on the digital computer. As before, the

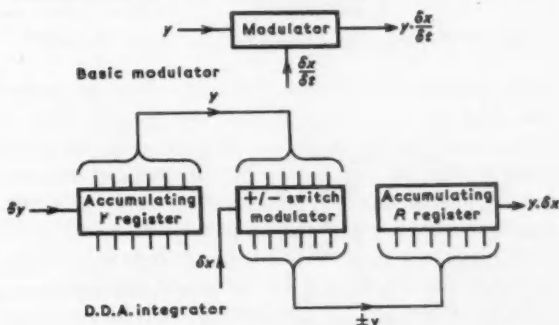


Fig. 6 Digital multiplication in d.d.a. integrator

d.d.a. could provide ancillary conversion and input-output facilities.

Fig. 7 illustrates what can be done with the auxiliary d.d.a. equipped with a suitable number of analogue-digital and digital-analogue converters. These are indicated by 'A.D.C.' and 'D.A.C.' respectively. An external input x_1 in digital form is converted to an analogue voltage for connexion to the analogue computer.

The analogue input x_2 is converted to digital form for use in the d.d.a. function generators.

A tape reader applies a digital programme x_3 to the d.d.a. equipment.

The analogue computer variables x_4 and x_5 are converted to digital form for use in the d.d.a. system. Functions F_1 and F_2 are generated by d.d.a. technique and converted to analogue form for use in the analogue computer. Similarly, function F_3 may be generated in the digital computer if available. It is possible for programmes such as F_4 and F_5 to be stored in either the auxiliary d.d.a. or the digital computer. An analogue computer variable x_7 is also shown connected to an analogue-digital converter for display as a digital voltage and print-out in digital form.

An auxiliary computer based on hybrid digital-anal-

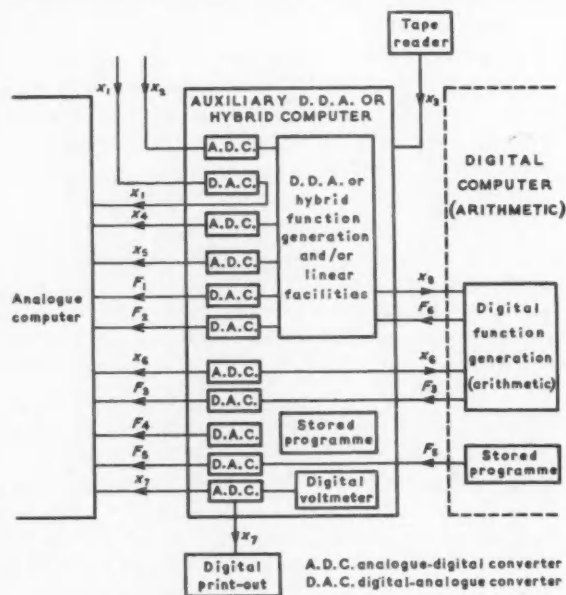


Fig. 7 Application of auxiliary d.d.a. or hybrid computer

logue technique is another possibility. The integrators here could be pure analogue ones, and possibly some of those in the existing analogue computer could be made available for this purpose by providing additional connexions to the auxiliary computer. It may be preferable, however, to insert plug-in integrators, as required, from a common stock. Individual non-linear units could, of course, be based on d.d.a. or hybrid techniques.

The combination of an auxiliary d.d.a. computer with a digital computer is an interesting arrangement which must be mentioned. This would permit much more advanced work than is possible in association with an analogue computer, as both linear and non-linear operations can be done with high accuracy. The auxiliary d.d.a. deals with the linear operations and some function generation, while the digital computer would be used for further functions, especially the difficult ones, and stored programmes. A typical interchange of variables for this case is shown by x_8 and F_6 in Fig. 7.

Conclusion

The computing difficulties arising in complex problems have been examined and it is seen that there is a trend towards the introduction of digital techniques, particularly in connexion with the generation of non-linear functions.

A general method has been described which is available for the synthesis of non-linear functions, and this uses integration as a basis. It involves numerous multiplications and integrations with respect to variables other than time, so an economic technique for performing these operations is essential.

This method of synthesis is the basis of d.d.a. technique; but it is theoretically possible to employ a similar method with hybrid digital-analogue technique, which offers the prospect of high speed of operation and reduced cost of equipment.

An analogue system also could be used, but there seems to be no attraction in a system of this kind, and accuracy could be low, although the high speed of analogue operation would result.

The fully-digital d.d.a. technique offers the most satisfactory general solution, and a complete d.d.a. installation would appear to be the logical outcome. There seems to be a place also, however, for an auxiliary d.d.a. computer alongside existing analogue computers, as this appears to be an excellent method of adding improved non-linear and other facilities. The maximum frequency of operation with this combination can be much higher than with a digital arithmetic computer. A further application could be in association with a digital computer for the most advanced work. Indeed various possibilities have been described, and Fig. 7 shows how the unit may be used also as a connecting link between a digital computer or external digital devices and an analogue computer.

Hybrid digital-analogue systems are possible, either as complete computing installations, or as an auxiliary computer, but accuracy will be less than with a d.d.a. system. These should be considered where moderate accuracy is sufficient and where higher speed of operation is required.

Acknowledgment

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VARIABLE-AREA FLOWMETERS

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Introduction

The rate of flow of a fluid in a pipe is commonly determined from the pressure difference produced by a constriction in the pipe. With an orifice of fixed size the flow is proportional to the square root of the pressure drop, and as a result the meter is of low sensitivity over the lower third of its range of flow measurement. The flowmeters which are the subject of this survey are so constructed that the size of the orifice is dependent on the flow and automatically increases as the flow increases; the size is then a measure of the flow and the meters are therefore known as *variable-area* or *area-type* flowmeters. The scale shape of such an instrument may be made linear by suitable design and it is then particularly suitable for use in chemical processing and manufacturing industries. Alternatively, the scale shape may be made non-linear with maximum sensitivity at the lower end of the range: this type is used in water supply undertakings for the detection of waste of water.

Tapered tube and float meter

The simplest practical design of variable-area meter consists of a vertical glass tube the internal diameter of which increases uniformly from bottom to top, enclosing a float whose external diameter is approximately the minimum internal diameter of the tube. The density of the float is greater than that of the metered fluid, which is introduced at the bottom of the tube and lifts the float until the pressure difference due to the fluid flowing through the annular orifice between float and tube is just sufficient to support the float. The height of the float is observed against a scale engraved on the glass tube. A design of float frequently used has diagonal grooves at the top,

causing it to rotate in the flow and remain clear of the tube walls. Other designs of float have to be guided, either by a rod passing up the axis of the tube, or by ridges or beads moulded in the glass. Constructional materials for these meters include glass, stainless steel, cast iron and plastic-lined or lead-lined cast iron for the tubes, and ceramic, light alloy, glass, stainless steel and heavy alloy for the floats.

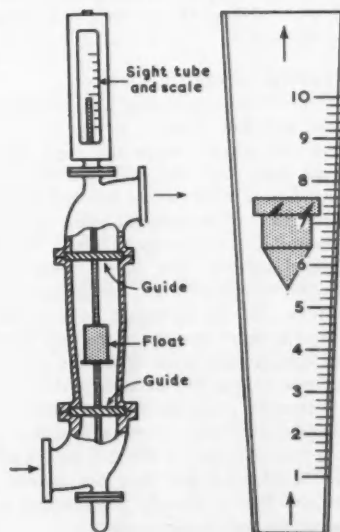
Theory shows that the displacement of the float is directly proportional to the flow if the flow is turbulent (see *Flow Measurement and Meters*, p. 196, by A. Linford, E. & F. N. Spon Ltd., 1949). If, because of high viscosity or low rate of flow, the flow is in the laminar or transitional region, the scale is no longer linear: the meter will be affected by any change in viscosity from that for which it was calibrated, and use must be made of correction curves supplied by the makers. The effect of viscosity is much less marked if the float has a sharp edge at its largest diameter. A viscosity-immune float can be used at a Reynolds Number 1/50 to 1/100 of the value at which the normal type begins to give errors; it must be guided, however, and the capacity of the meter is reduced by some 20%.

Fluid density changes affect the apparent weight of the float. The actual flow can be found by multiplying the indicated flow in volumetric units by $[(W_f - W_n)W_m / (W_f - W_m)W_n]^{\frac{1}{2}}$, where W_f , W_n , W_m , are the float density, actual fluid density, and calibration fluid density respectively. When the meter is calibrated in weight units, the factor is $[(W_f - W_n)W_n / (W_f - W_m)W_m]^{\frac{1}{2}}$. If $W_f = 2 W_m$, and there is no great difference between the actual and calibration fluid densities, the latter factor is nearly unity, and the float is density-immune, a $\pm 10\%$ difference in density producing

less than $\pm 0.5\%$ error. The capacity of the meter, however, is only about 30% of that with a normal float. For gases, W_n and W_m are negligible compared with W_f , and the factors reduce to $(W_m/W_n)^{\frac{1}{2}}$ and $(W_n/W_m)^{\frac{1}{2}}$.

The head loss in the flowmeter tube will normally be small and constant, being nearly equal to the effective weight of the float divided by its area. In a practical installation the head loss due to the bends required to fit the instrument into a run of piping may be much greater than the head loss in the meter tube and will increase with increasing flow. The ratio of maximum to minimum flow for any particular combination of tube and float is normally 10:1, but may be less for viscosity-immune and density-immune meters. The available ranges of glass tube meters cover flows from 0.007

Tapered tube and float meters: metal tube on left, glass tube on right



This survey is published by courtesy of the Director, Hydraulics Research Station.

CONTROL 15 SURVEY

to 4200 gal/h of water, and 0.09 to 18,000 ft³/h of air at standard temperature and pressure (70°F, 14.7 lb/in²).

For larger flows the metering tube is made of metal and the float has an extension projecting into a graduated sight glass. Alternatively, the extension may operate an electric or a pneumatic transmitter, the output driving a remote indicator, recorder, or a servo system for plant control. The metal-tube design will stand a higher operating pressure than a glass tube meter. For still higher pressures the meter has a float of magnetic material in a non-magnetic tube, usually of stainless steel. Movement of the float is followed by an external magnet coupled to an indicating pointer or a pneumatic or electronic transmitter. Magnetic coupling is sometimes also used in meters designed for corrosive fluids at lower pressures, the tube being made of glass and the float being a magnet enclosed in p.t.f.e.

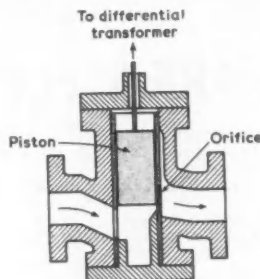
Pneumatic transmitters are usually intended to work with a remote controller or indicator requiring the recommended B.S. 3 to 15 lb/in² pressure range, but may be designed for any reasonable range of transmitted pressure; the remote instrument may be several hundred feet away from the transmitter. Electric transmitters may give a d.c. or a.c. signal, and the receiver may again be remote from the transmitter.

Tapered tube and float meters are not appreciably affected by non-axial flow caused by pipe bends or partially closed valves, and the major precaution required in installing a meter is to see that the tube is vertical. If the tube is not vertical it will read fast, the indicated flow being greater than the actual flow by about 1% for 10° inclination. Because the scale is linear, pulsating flows are correctly averaged, but it is possible for a condition of resonance to be set up when metering pulsating air flows, resulting in excessive movement of the float.

Piston-type meter

Piston-type flowmeters, like the metal tube and float type of meter, are suitable for opaque fluids and high pressures. They may be used for very viscous liquids such as hot tar, and heavy fuel oils. The essential parts of the instrument are a weighted piston and a vertical cylinder, the latter containing the piston and having a rectangular slot on one side. In its lowest position the piston is below the end of the slot: when the fluid is introduced below the piston, the piston rises and exposes part of the slot through which the fluid escapes. The pressure difference across the orifice is then just sufficient to support the weight of the piston, and is therefore constant, and the flow is directly proportional to the displacement of the piston.

The movement of the piston operates a pneumatic or electrical transmitter. An electrical system using a differential-transformer-type transmitter can be used over distances as great as 3000 ft, and with a re-transmitter up to several miles. For high flows or very viscous fluids the weight of the piston may be supplemen-



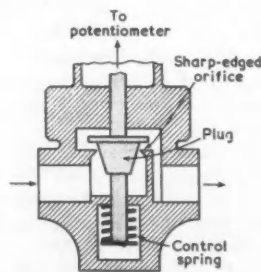
Piston-type flowmeter

ted by a spring. The ratio of maximum to minimum flow is 50:1, as compared with the 10:1 ratio for the tapered tube and float.

Piston-type flowmeters are slightly affected by non-axial flow, and it is advisable to have a straight run of 15 to 20 diameters of horizontal pipe before and after the meter. The maximum flow of a particular meter may be changed by altering the weight of the piston, the maximum flow being proportional to the square root of the weight, or by changing the orifice width, to which maximum flow is directly proportional.

Tapered plug and orifice meter

Another form of linear-scale, variable-area, flowmeter has recently been developed for measuring flow in high pressure hydraulic systems. It comprises a tapered plug which moves axially in a sharp edged orifice and is loaded by a spring. Fluid flowing through the meter displaces the plug to an extent depending on the rate of flow: linearity is



Tapered plug and orifice flowmeter

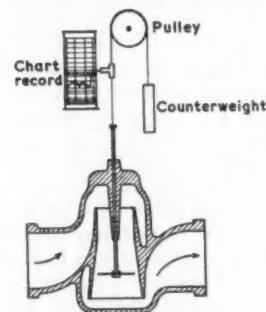
achieved by correct choice of the spring rate and initial set, and of the taper of the plug.

Movement of the plug is measured electrically by a potentiometer, the slider being moved by the plug. The potentiometer is part of a d.c. bridge

energized by a battery, and the flow is indicated on a moving-coil meter.

Cone and disk meter

The cone and disk meter is generally used for water metering, and is designed for installation in a horizontal run of pipe. The instrument comprises a hollow truncated cone with its axis vertical and larger diameter at the bottom. A flat disk, or piston, just fits the smaller end of the cone and is supported by a wire which passes over a pulley to a counterweight. Water is fed in above the disk and forces it down until the waterway between the disk and cone is sufficient to pass the flow, and a pen attached to the wire records movement of the disk on a chart mounted on a vertical drum. Whereas in the tapered tube and float meter the motion of the float is wholly within the tube, it is possible for the disk to pass beyond the end of the cone, resulting in a rapid loss of sensitivity and a very wide range. A typical instrument has a linear calibration over the first 25% of its range, a gradually



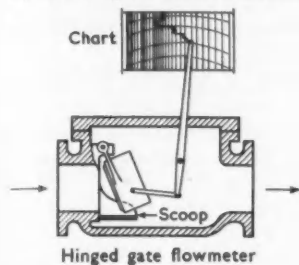
Cone and disk flowmeter

decreasing sensitivity over the next 20%, and then rapidly decreasing sensitivity over the remaining 55%, which occupies only 20% of the total movement of the disk. The flow range is approximately 200:1 and the accuracy of registration is ± 2 to 3% over the whole range. The accuracy of the meter is not appreciably reduced by the proximity of bends and valves, but it is important that the meter is truly vertical.

Gate meter

The gate-type variable-area meter resembles a flap-type, non-return valve. A weighted gate is suspended on a knife edge, and when no flow is passing the gate rests against and closes an orifice. The gate is raised by the flow until its weight is balanced by the differential pressure across the aperture between the gate and orifice. Motion of the gate is conveyed to a spindle rotating in a pressure-tight gland, and thence to a recording pen. A special scoop is fitted on the downstream side of the orifice, shaped so as to increase the displacement of the gate for a given flow; this scoop in-

increases the sensitivity over the lower part of the flow range, the ratio of maximum



to minimum flow being about 300:1. The meter is usually adjusted to agree with a printed scale, and the accuracy is then

about $\pm 1\%$ f.s.d. If, however, the meter is individually calibrated, the accuracy is ± 2 to 3% of the indicated flow.

Specialized flowmeters

To conclude this brief description of variable-area flowmeters it may be of interest to mention two specialized instruments. The first is a tapered tube and float meter developed to measure the flow of drying-air through grain in silos. It consists of a tapered graduated plastic tube and a float in the form of a thin aluminium disk, guided by a fine wire in the centre of the tube. The bottom end of the tube is placed on the grain and the disk rises to indicate the flow.

The range is 7 to 26 ft/min and the accuracy $\pm 1\%$, with an approximately linear scale.

The second instrument is a linear air flowmeter with a rapid frequency-response for use in studies of respiration. It consists of a box, one side of which is a spring-loaded diaphragm closing an outlet tube. Air passing into the box forces the diaphragm away from the outlet to an extent depending on the rate of flow. The diaphragm is coupled to a displacement transducer which gives an electrical signal. Full-scale deflexion may be obtained for flows from 1250 to 11,000 ft³/h with a pressure drop of less than 1 in. water.

COMMERCIALLY AVAILABLE FLOWMETERS

Accuracy is expressed as a percentage of indicated flow (i.f.) or of full-scale deflexion (f.s.d.). Maximum working pressure given is for liquids; for gases it is almost invariably much lower. Makers should always be consulted. The maximum flow for a meter will lie within the range shown. Minimum flow for that meter will be a tenth of the maximum flow, except where noted in remarks.

TYPE	MANUFACTURER	AVAILABLE RANGE OF MAXIMUM FLOW		APPROXIMATE SCALE LENGTH (in.)	HEAD LOSS		MAXIMUM WORKING PRESSURE (lb/in. ²)	ACCURACY	END FITTINGS	MANUFACTURER'S TYPE NO.	REMARKS
		WATER (gal/h)	AIR (ft ³ /h)		WATER (in. water)	AIR (in. water)					
TAPERED TUBE AND FLOAT (GLASS TUBE)	Drallim Industries Ltd.	1 and 3	0.5 to 2	1½	½ and 2	½ and 2	250	$\pm 3\%$ f.s.d.	Internally threaded ½ in. B.S.P.T.	Size 2	Optionally fitted with nozzles for flexible pipes or compression couplings for rigid pipes. Some meters have flow range less than 10:1.
	Tick No. 801	10 to 60	4 to 200	4				$\pm 1½\%$ f.s.d.	Internally threaded ¼ and ½ in. B.S.P.T.	Sizes 6 and 10	
	G. A. Platon Ltd.	250 to 1000	250 to 1000	15				$\pm 1½\%$ f.s.d.	Internally threaded ½, ¾ and 1 in. B.S.P.T.	Sizes 15, 19 and 25	
	Tick No. 802										
Fischer and Porter Ltd.	Tick No. 803	0.0075 to 27.5	0.09 to 74	5	0.12 to 2.7	0.17 to 3.0	550 to 440	± 2 to 3% f.s.d.	Screwed or flanged for vertical or horizontal pipes	Series 2700 Triflat Tube	The floats are spherical. These meters have a non-linear calibration at low flow-rates due to operation in the laminar-flow and transitional-flow regions.
							100	$\pm 2\%$ f.s.d. calculated, $\pm 1\%$ f.s.d. calibrated	Internally threaded ½ in. B.S.P.T.	Series 500	
							25	$\pm 2\%$ f.s.d. calculated, $\pm 1\%$ f.s.d. calibrated	½ in. rubber or plastic hose	Series 1017	
		13 to 4200	67 to 18,000	10	0.8 to 13		300 to 100	± 2 to 3% f.s.d.	Screwed or flanged for vertical or horizontal pipes	Series 2700 Bead guided	
							50 to 25	$\pm 2\%$ f.s.d. calculated, $\pm 1\%$ f.s.d. calibrated	Glass flanges for ½ to 2 in. vertical pipes	Series 1028	
		13 to 600	67 to 3000	10	0.8 to 2.5		50	$\pm 2\%$ f.s.d. calculated, $\pm 1\%$ f.s.d. calibrated	½ to 1½ in. rubber or plastic hose	Series 1027	
		2 to 20	10 to 108	10			500	$\pm 2\%$ f.s.d.	Screwed or flanged for vertical or horizontal pipes	Series 100	
		0.01 to 20	0.14 to 106	1½	0.06 to 1.2	0.1 to 1.3	100	$\pm 4\%$ f.s.d.	Rear facing ½ in. N.P.T. female or A.P.I. or B.S.P.T.	With valve, Series 1115 Without valve, Series 1020	
		21.5 to 1560	36 to 3900	1½ to 4½			175 to 75	$\pm 2\%$ f.s.d.	Internally threaded ½ to 1½ in. N.P.T.	10A2235	
		6 to 3700	30 to 14,400					$\pm 2\%$ f.s.d.		Series 300.100	
Magnetic coupling to indicator and/or recorder and/or integrator.		1080 to 330,000		5 and 10	25 to 400		200	$\pm 2\%$ f.s.d.	Threaded ½ in.	Series 10 B 1700	The meter in series with an orifice is connected across an orifice in the main pipe and meters a fraction of the total flow. Total flow is shown at left.

Table continued on page 128

COMMERCIALLY AVAILABLE FLOWMETERS *continued*

TYPE	MANUFACTURER	AVAILABLE RANGE OF MAXIMUM FLOW		APPROXIMATE SCALE LENGTH (in.)	HEAD LOSS		MAXIMUM WORKING PRESSURE (lb./in. ²)	ACCURACY	END FITTINGS	MANUFACTURER'S TYPE NO.	REMARKS
		WATER (gal/h)	AIR (ft ³ /h)		WATER (in. water)	AIR (in. water)					
TAPERED TUBE AND FLOAT (GLASS TUBE)	The Rotameter Mfg. Co. Ltd. Tick No. 804	0.026 to 3000	0.2 to 5500	8 to 20	0.5 to 18.5	0.5 to 2.6	500 to 120	$\pm(2\% \text{ i.f.} + 0.3\% \text{ f.s.d.})$ for small meters $\pm 2\% \text{ i.f.}$ for medium and large meters	Glass flanges for $\frac{1}{2}$ to 3 in. pipes	102	'Letter' series instruments are individually calibrated.
									Flanged for vertical pipes $\frac{1}{2}$ to 3 in.	107	
									Flanged for horizontal pipes $\frac{1}{2}$ to 3 in.	114	
									Unions for $\frac{1}{2}$ to $1\frac{1}{2}$ in. B.S.P. and $\frac{1}{2}$ in. A.P.I.	125	
									$\frac{1}{2}$ to 1 in. rubber tube pushes on to ends of meter	Metric 100	
									$1\frac{1}{2}$ to 3 in. rubber hose and clips	Metric 101	Tubes and floats in the 'Metric' series are standardized for rapid replacement from stock without re-calibration.
		5.3 to 66	21 to 190	10 to 10	0.5 to 4	0.25 to 1.5	500 to 120	$\pm 6\% \text{ f.s.d.}$ to $\pm 3\% \text{ f.s.d.}$ $\pm 3\% \text{ f.s.d.}$ to $\pm 2\% \text{ f.s.d.}$	Glass flanges for $\frac{1}{2}$ to 3 in. pipes	Metric 102	
									Flanged for vertical pipes $\frac{1}{2}$ to 3 in.	Metric 107	
									Unions for $\frac{1}{2}$ to $1\frac{1}{2}$ in. B.S.P.T.	Metric 125	
									Unions for $\frac{1}{2}$ to $1\frac{1}{2}$ in. B.S.P.T.	900	
									Flanged for vertical pipes $\frac{1}{2}$ to 2 in.	907	
									Flanged for horizontal pipes $\frac{1}{2}$ to 2 in.	914	
		0.007 to 45	0.004 to 85	8			Low	$\pm(2\% \text{ i.f.} + 0.3\% \text{ f.s.d.})$	Internally threaded, or cone type, connectors	825 large	Can be fitted with valve. Cast and fabricated cases are available for multiple assemblies.
		0.007 to 10	0.004 to 35	4			Low	$\pm(5\% \text{ i.f.} + 0.5\% \text{ f.s.d.})$	Internally threaded or cone type connectors	825 small	
		0.007 to 5	0.004 to 15	1 to $1\frac{1}{2}$			Low	$\pm(10\% \text{ i.f.} + 1\% \text{ f.s.d.})$ limited to three calibration lines	Internally screwed	704	May be fitted with valve.
								$\pm 2\% \text{ i.f.}$	Flanged for vertical pipes 1 to 2 in.	507	Magnetic coupling to external pointer. For use with corrosive or opaque liquids.
									Flanged at top for horizontal or vertical pipes. Flanged at bottom for horizontal pipes 1 to 2 in.	514	
		110 to 2100	300 to 5400	6	5 to 16	1 to 3	250		Flanged for vertical pipes 1 to 2 in.	407	Pneumatic transmission to remote receiver, 3 to 15 lb./in. ² range. Also electrical transmission, Type 300 meters.
									Flanged at top for horizontal or vertical pipes. Flanged at bottom for horizontal pipes 1 to 2 in.	414	
								$\pm(2\% \text{ i.f.} + \frac{1}{2}\% \text{ f.s.d.})$			
								$\pm \frac{1}{2}\%$		850/3	Three special Rotameters in series for wide range. For example, 250 to 40,000 lb./h of kerosene.
TAPERED TUBE AND FLOAT (METAL TUBE)	Fischer and Porter Ltd. Tick No. 805	70 to 14,500	290 to 60,000	5	25 to 80			$\pm 2\% \text{ f.s.d.}$ standard $\pm 1\% \text{ f.s.d.}$ special $\pm 2\% \text{ f.s.d.}$ standard $\pm 1\% \text{ f.s.d.}$ special	Flanged for vertical inlet, horizontal outlet pipes 1 to 3 in.	10A1152	Can be fitted with indicator, electrical transmitter, or pneumatic transmitter. Can be steam jacketed. Operates up to 1000°F.
									Flanged for vertical inlet, horizontal outlet pipes 1 to 3 in.	10A1151	Flow range may be up to $12\frac{1}{2}$: 1 Operates up to 1000°F.

COMMERCIALLY AVAILABLE FLOWMETERS *continued*

TYPE	MANUFACTURER	AVAILABLE RANGE OF MAXIMUM FLOW		APPROXIMATE SCALE LENGTH (in.)	HEAD LOSS		MAXIMUM WORKING PRESSURE (lb./in. ²)	ACCURACY	END FITTINGS	MANUFACTURER'S TYPE NO.	REMARKS
		WATER (gal/h)	AIR (ft ³ /h)		WATER (in. water)	AIR (in. water)					
TAPERED TUBE AND FLOAT (METAL TUBE)	Fischer and Porter Ltd. (contd.)	5580 to 261,600			47 to 500		300	±2% f.s.d. standard ±1% f.s.d. special	Flanged for vertical inlet, horizontal outlet pipes 2 to 8 in.	10A1156A	Can be fitted with indicator, electrical transmitter, or pneumatic transmitter. Operates up to 900° F.
		4 to 115		2	50 to 10		3000	±2% f.s.d.	Threaded ½ in. N.P.T., or flanged	585/E.	Can be fitted with indicator or pneumatic transmitter. Operates up to 500° F.
	The Rotameter Mfg. Co. Ltd. Tick No. 806	2400 to 90,000	7200 to 180,000	11 to 8	36 to 48	6	500	±2% i.f. (±2% i.f.) +½% f.s.d. including receiver	Flanged for vertical or horizontal pipes 1½ to 8 in.	Series 150 Series 470 Series 670	With sight glass. With pneumatic transmitter, 3 to 15 lb./in. ² range. With electrical transmitter, a.c. differential transformer type.
		70 to 2500	720 to 5100	6	5 to 16	1 to 3	1000	±2% i.f. (±2% i.f.) +½% f.s.d.	Flanged for vertical or horizontal pipes 1 to 2 in.	Series 500 Series 400 Series 300	Magnetic coupling to external pointer, for use with corrosive or opaque fluids. Up to 600° F. With pneumatic transmitter, 3 to 15 lb./in. ² range. With electrical transmitter, 0 to 30 mA d.c.
							5000	±2% i.f.	Flanged for vertical or horizontal pipes 1 to 2 in.	550	Magnetic coupling to external pointer, for use with corrosive or opaque fluids.
		No Fixed Standards					5000			450	With pneumatic transmitter, 3 to 15 lb./in. ² range.
		0.3 to 1870					1000	±(2% i.f.) +½% f.s.d.	High pressure unions, or flanged for vertical pipes	640	With electrical transmitter, a.c. differential transformer type.
PISTON	Bailey Meters and Controls Ltd. Tick No. 807	63 to 890			6				Flanged for 1 in. horizontal pipes	JR1141*	Weight loaded. Low viscosity, clean fluids.
		147 to 2150			276		600	±2% f.s.d.		JR1143*	Spring loaded. Suspensions and high viscosity fluids.
		1100 to 1830			6				Flanged for 2 in. horizontal pipes	JR1141*	Weight loaded.
		2560 to 4275			276					JR1143*	Spring loaded. *All sizes are fitted with electrical transmitters. Pneumatic also available.
	Honeywell Controls Ltd. Tick No. 808	150 to 2000	Not recommended for gases		10 to 27		250 or 600	±2% f.s.d.	Flanged for 2 in. horizontal pipes	Series 293A2	With electrical transmission. Can be fitted with cooling fins for hot liquids up to 600° F., or with steam jacket for very viscous liquids.
TAPERED PLUG AND ORIFICE	Sir W. G. Armstrong-Whitworth Aircraft Ltd. Tick No. 809	300 and 600			180 and 720		4500	±2% i.f. (½ f.s.d. to f.s.d.) ±5% i.f. (0 to ½ f.s.d.)	Internally threaded ½ in. B.S.P.	TDD 101/1 and TDD 101/2	If used to meter gases, minimum pressure is 250 lb./in. ² for TDD 101/1; 1000 lb./in. ² for TDD 101/2; 500 lb./in. ² for TDD 101/4, and 1000 lb./in. ² for TDD 101/5.
		1200 and 1800			315 and 675		6000	±2% i.f. (½ f.s.d. to f.s.d.) ±5% i.f. (0 to ½ f.s.d.)	Internally threaded 1 in. B.S.P.	TDD 101/4 and TDD 101/5	
CONE AND DISK	Monitor Patent Safety Devices Ltd. Tick No. 810	300							Flanged for horizontal pipes ½, 1, or 1½ in.	Size 1	
		600		6	27½				Flanged for horizontal pipes 1½, 1½, or 2 in.	Size 2	
		1200							Flanged for horizontal pipes 2½, 2½, or 3 in.	Size 3	
	Palatine Engineering Co. Ltd. Tick No. 811	10,000 to 45,000		7	96 to 36			±2 to 3% i.f.	Flanged for water mains 3 to 10 in.		Flow range is 200 : 1. Records on metallized paper chart by gold point or ball point pen.
HINGED GATE	George Kent Ltd. Tick No. 812	10,000 to 100,000		7	30		150	±2 to 3% i.f. if specially calibrated.	Flanged for water mains 3 to 12 in.		Flow range is 300 : 1. Records by ball point pen. Instrument is normally adjusted to approximate agreement with printed chart.

PEOPLE IN CONTROL

by Staffman



BORISENKO SCHILLING
from Moscow . . .

S.I.M.A. appear to have timed their Moscow exhibition rather nicely, for it overlaps with I.F.A.C.'s Moscow Congress on Automatic Control. Some 34 S.I.M.A. members will show their wares in Moscow's Polytechnic Museum from June 18-29, and the I.F.A.C. Congress covers June 27-July 6. My heading illustration shows the contract for the exhibition being signed by **D. G. Borisenko**, Vice-President of the Soviet All Union Chamber of Commerce, and **Peter Schilling** of Stanton Instruments and Chairman of S.I.M.A.'s Export Committee. Standing behind the signatories are—left to right—**K. I. Smolianov**, Head of the U.S.S.R. Foreign Exhibitions Department, **P. G. Brigadnov** and **D. M. Serov** of the All Union Chamber of Commerce, **G. A. Chard** of Lep Exhibitions, **Hilary King**, Commercial Counsellor of the U.K.'s Moscow Embassy, and S.I.M.A.-member **Hugh D. Binyon** of Solartron.

The leading article (p. 97) mentions **A. G. Ivahnenko** of the U.S.S.R. Academy of Sciences who has been lecturing in this country, and my



MARTIN COPPIN to Southend
IVAHNENKO FISHER

photograph shows him examining Ekco machine-tool control equipment. Among others in the photograph are (from left) **A. W. Martin** and **K. J. Coppin** of Ekco Electronics; **A. S. Fisher** has his back to the camera.

I came across a thought-provoking statement by **Robert Broadbent**, Chairman of Sperry Gyroscope, in a recent copy of *Sperry Review*. He says 'A year or two ago . . . it was widely thought that the volume of aeronautical business, as distinct from guided missile work, available to companies such as Sperry would show a very rapid decline, but to-day we have under development a larger number of new aircraft instruments and control systems for both civil and military purposes than almost at any time in our history.' So much for the decline and fall of the aircraft industry.

I asked **D. R. Hunt**, who has just become General Manager of Alto Instruments, for his impressions on returning to the flowmeter world—he left Fischer & Porter, where he was Sales Manager, to spend a year as Commercial Manager with Plessey-subsidary Power Auxiliaries. 'To put it bluntly' he said 'I am glad to be back because I believe there is a bigger future in instruments.'

There have been several interesting appointments within the Plessey group recently. **R. E. Leach** (ex-Ministry of Supply, Bristol Aero Engines and Sperry Gyroscope) becomes Regional Personnel Manager for the Swindon area, and **E. J. Hudson** (ex-Brush Electrical and Jackson Industries) Divisional Manager of the Plessey (Swindon) General Services Division. I understand that **E. F. D. Webb**, who has been appointed Engineering Manager of Hagan Controls, is just back from the U.S. where he has been in-

vestigating American methods of automatic process control. Webb was Technical Director of Ipscol, designing combustion and process control systems, and from 1953-1958 was Chief Engineer of Fuel Firing. Semiconductors' new Sales Manager, **J. H. Thorp**, has also had an interesting career. He worked under **P. M. S. Blackett** and **H. E. Buckley** at Manchester, was with the Armament Research Establishment and transferred to T.R.E. (now R.R.E.), Malvern, in 1950, joining Texas Instruments in 1957. Thorp is,



WINTERBOTTOM
recorder



WEBB
controller

of course, responsible to Semiconductors' Commercial Executive Director, **C. H. Noton**.

I knew **J. F. Winterbottom** when he was in charge of instrumentation at the Motor Industry Research Establishment and I was, therefore, most interested to hear of his appointment as Chief Engineer of I.C.T.-associate Data Recording Instrument Co. He tells me that the company intend expanding their activities in the analogue field and also that 'we hope to investigate the fundamental problems of extracting wanted information from long or sampled lengths of recorded data.'

Hearing that **C. H. Barden**, who joins the Technical Sales Department of Smiths Aviation Division, is an R. & D. man from Smiths Cheltenham organization, with a considerable back-

ground knowledge of autopilot development, I quizzed Smiths on autopilot trends. They tell me that 'autocontrol' is becoming a more complex subject, this being dictated by stringent air traffic control requirements. These, although not affecting the autopilot directly, place a greater strain on human pilots, leading them to look for more help from their automatics.'

After nine years as General Manager of E.M.I. Electronics' Wells factory,

W. Pigdon is now in Halifax, Nova Scotia, as Executive Vice-president of E.M.I. - Cossor Electronics — E.M.I.'s Canadian subsidiary. I gather that the idea is to graft a number of Hayes projects on to the Canadian factory. Following a recent visit to Canada, **Clifford Metcalfe**, E.M.I. Electronics' Managing Director, said: 'I am very hopeful that we can help the electronic industry of Canada by transplanting some of the tremendous know-how at Hayes.' **Edward Bagley** is taking over

Pigdon's duties at Wells and will be responsible to **P. A. Allaway**, who is Deputy Managing Director of E.M.I. Electronics Ltd.

I hear from **J. Bown**—who signs himself Secretary—that he and three other ex-employees of Lang Pneumatic, **W. H. Currie**, **B. Davis** and **J. Hibbert**, are available for consultation on pneumatic control matters at 2 Compton Road, Wolverhampton—telephone: 27249.

AUTHORS IN CONTROL

R. B. Larkinson (*Analogue-computer analysis of rolling-mill controls*, page 105) read mathematics at Merton College, Oxford, and graduated with a Second Class Honours degree in 1952. After leaving Oxford he spent a short period with an insurance company and later was at A.E.R.E. Harwell. He joined English Electric as a Graduate Apprentice in 1954 shortly after which he obtained an H.N.C. in Electrical Engineering at Stafford Technical College. Since 1956 he has been with English Electric's Metal Indus-



LARKINSON

tries Division where he has been concerned with the analysis of the many types of servo system used in the steel industry.

P. D. Boyer (*Hydraulic servos*, page 115) had an aircraft engineering apprenticeship with Flight Refuelling and joined High Explosives Research (H.E.R.), Fort Halstead, where he worked on atomic weapons research, in 1948. There he was concerned with the development and application of high-speed camera drives and originated the 100-200,000 rev/min turbine mirror-drives now embodied in the Barr and Stroud camera. He joined Elliott Brothers (London) in 1952, forming and heading their Hydraulics Group at Boreham Wood—*inter alia* designing and producing their current range of adjustable-lap servo-valves. In July 1958 he joined English Electric where he designed two new linear valves. He heads the Servovalve Sec-

tion set up for their development and manufacture.

R. J. A. Paul (co-author with M. E. Maxwell—below—of *Digital and hybrid simulation techniques*, page 120)



PAUL

is a First Class Honours graduate of London University. For six years he was a research engineer at the Motor Industry Research Association where he was mainly concerned with measurement and instrumentation techniques. He spent two years at Sperry Gyroscope working on the control aspects of a guided missile project, and four years with Short Brothers & Harland. Paul was Head of the Electronics Section of Short's Research Department, and responsible for a number of projects including the Short computer and control systems for guided missiles. He is a consultant to Short's. For the past three years he has been Deputy Head of the Electrical Engineering Department of the College of Aeronautics, Cranfield.

M. E. Maxwell graduated from Queen's University, Belfast, in 1938 and joined the Technical Office, Short Brothers & Harland. From 1943 until 1947 he was with the Admiralty Signal Establishment working on the development of v.h.f. communications and, later, on u.h.f. television research. After a period in British European Airways' Research Section at Northolt, assessing radio systems, he joined the Radar Laboratory of Ferranti,

Edinburgh. He was a project engineer at Ferranti, working on marine radar and the 1000-Mc/s d.m.e. beacon, until re-joining Short Brothers in 1952 as Head of the Analytical Group, Research Department. He is concerned with project assessment in computation, automatic control, and aircraft and g.w. system studies.

M. J. Wilkie (*Variable-area flowmeters*, page 125) is in charge of a section of the Hydraulics Research Station, D.S.I.R., which is responsible for the design and development of field and laboratory instruments for the measurement of water level, velocity, depth, temperature, salinity, etc. He joined the newly formed Hydraulics Research Organization, now known as the Hydraulics Research Station, in 1949, having previously been a member of the staff of the Engineering Department of the National Physical Laboratory. At the N.P.L. he worked on fluid film and boundary lubrication. During the war he directed his attention to the design and development of instruments required for the investigation of these problems and of problems to do with fatigue and stress analysis. He holds a General Science degree and a Physics degree of the University of London, obtained by part-time studies at the Chelsea and Battersea Polytechnics.

D. A. Miller (*Practical solution of quartic and cubic equations*, page 133) is a graduate of University College, London, where he gained an honours degree in mathematics. His first post was with de Havilland Propellers where he worked on the analysis of vibration and vibration stresses. For the past two years he has been with E.M.I. Electronics engaged on theoretical work associated with g.w. development, including servo-mechanism design and analysis.

Pick-off

by 'UNCONTROLLED'

I WAS interested to see in last month's leader that the Editor used the word 'automatization' rather than the popular (vulgar?) 'automation'. I have myself overcome my distaste for it and grown to accept the contracted form, but resistance is cropping up in all sorts of places. In the March issue of *Automatik*, for instance. I came across an amusing piece entitled 'Automation' oder 'Automatisierung'? ('Automation' or 'Automatization'?) and sub-headed 'Die Uebernahme des englischen Ausdrucks führt im Deutschen zu einer Begriffsverwirrung' ('Adoption of English Expression Leads to Confusion in German'). The writer, Dr. Hans Roeper, deplores the modishness of this vague foreign word in German speech, and attacks it on grounds philosophical as well as xenophobic. He points out that German official and academic circles also disapprove of the immigrant, but he thinks that the word is all right in English because it makes the language easier. However, a quick count of the letters after the first three syllables suggests to me that the longer German word would be exactly as much more difficult for English-speakers as the longer English word would be for Germans, and both would be equal mouthfuls for natives. I agree with Dr. Roeper that 'automation' has lost its pristine precision, and on that count I would gladly reject it. But I am not altogether convinced that to restore two syllables is to restore clarity.

I SEE that the I.L.O. agrees with me (see *Pick-off* last month) in finding the distinction between 'automation' and 'mechanization' rather nebulous. In a pamphlet just issued, based on David A. Morse's report to the 1957 Session of the I.L.O., I read that:

'While automation means many different things to many different people, most people would place under that head all those technological developments

—which expand mechanisation to the point where production lines are almost automatic with little or no handling of materials;

—which extend automatic control (feed-back control) over manufacturing operations so that the process becomes virtually self-regulating;

—which involve electronic computer processing of data and information so that increased and refined automatic controls extend into the very heart of industry, commerce and government.'

This is pretty wide, but appears to leave out a few things. Feedback control, for instance, is used in important activities other than 'production'. Almost, the term 'auto-

quently portrayed beside a component. 'Is it,' he demanded, 'a giant threepenny-bit? Or is it the genuine article, and if so does it bear any relationship to the cost of the product? Further, is it always the same coin, whether real or false?' He expanded his theme by pointing out that CONTROL's overseas readership may never have seen a threepenny-piece, and would therefore have no notion of its size or value.

He was probably pulling my leg; nevertheless, the point has some validity. Perhaps an adventurous photographer will broaden our horizon by using a rouble or a yen; use of a scale might be too revolutionary.

We are considering an annual award for the best suggestions from readers for such standards: the prize might well take the form of a mint-condition threepenny-piece.

Auto-mating



mation' seems to have become as all-embracing and indefinite as 'engineering' itself. Perhaps the two domains—if domains they are—will soon become co-extensive in fact as well.

Under the heading *What is new about automation?* the pamphlet lists, first 'automatic methods of production', second 'continuous flow production', and third the possibility of completely automatic factories. After this comes the anticlimactic statement, 'In fact, of course, automation is not new'. Of course.

I MET a reader the other day who had a curious query about *New for Control*—or rather, about the pictures in that feature. He wanted to know about the ubiquitous threepenny piece so fre-

VOGUE words are not always reprehensible, and some pass permanently into the language with beneficial effect. But one that I cannot feel happy about, though it seems to be becoming part of usage, is *parameter*. In my youth I was introduced to it as an independent variable, functions of which might express other variables. I grew to discover that it may also mean a constant of a system. In fact, it seems to have become a typical example of pre-1984 scientific double-think. I have before me a technical dictionary which defines it as 'An arbitrary constant, as distinguished from a fixed or absolute constant. . . Any desired numerical value may be given to a parameter'. Question: is a parameter a variable constant or is it a constant variable?

Practical solution of quartic and cubic equations

by **D. A. MILLER, B.Sc.**
G.W. Division, E.M.I. Electronics Ltd.

In engineering problems such as the determination of the response of servo-mechanisms, accurate practical methods of solution of equations of up to the fourth degree are often required. This article presents direct simple step-by-step methods of solution of quartic and cubic equations.

The methods can be applied with a desk calculating-machine using square-root and cube-root tables, and with a digital computer provided that suitable methods of cube-rooting and square-rooting can be programmed.

In general, the solution of quartic equations by the standard method (1) demands considerable mathematical skill since it requires the solution of a cubic equation with real coefficients and of four quadratic equations with possibly complex coefficients. For fourth degree characteristic equations a solution has been published (2), but this requires the use of special curves in addition to calculations.

The method of solution of cubic equations presented may also be found in a previous publication (3) and is included here for completeness. It has been put in a convenient form for computation, and instructions for dealing with special cases have been added, as with the quartic equation solution.

Both the solutions proceed from coefficients to explicit roots. The mathematical operations required are the same as those used in the solution of quadratic equations except for a single cube-root evaluation in one of two cases.

Uses of These Methods

Examples of the uses of these methods in servo system design are in the solutions of the characteristic equations and the determination of the border-line unstable gain settings for different values of the system parameters, when the equations are

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not of above the fourth degree. The solution of equations of above the fourth degree is in general not possible by steps such as in the above solutions but requires approximating methods such as Graeffe's method. In some cases the order of a characteristic equation may be usefully reduced by approximations in the transfer functions. In the calculation of the response of a servo system the solution of the characteristic equation is usually the greatest obstacle.

Conclusion

The methods presented enable quartic and cubic equations to be solved with speed and the minimum mathematical difficulty, and without graphical measurements. Small approximations have been made which eliminate the need for the use of trigonometric tables, but the accuracy of the methods is well above the usual engineering requirements.

Published by courtesy of the Management, E.M.I. Electronics Ltd.

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3. Sullivan, G. L., 'Practical Solution of Cubic Equations,' Machine Design, Feb. 1957.

TABLE I Solution of $a_0x^4 + a_1x^3 + a_2x^2 + a_3x + a_4 = 0$

EXAMPLES: 1. $x^4 + 7x^3 - 7x^2 - 43x + 42 = 0$ (roots 1, 2, -3, -7)
2. $x^4 + 10x^3 + 46x^2 + 146x - 203 = 0$ (roots 1, -7, -2 ± 5j)

	(A)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Column Heading	$\frac{1}{a_0}$	$\frac{a_1(A)}{4}$	$\frac{a_2(A)}{6}$	$\frac{a_3(A)}{4}$	$a_4(A)$	$\frac{1}{2}[(4)-(1)(3)+3(2)^2]$	$(2)^2-(4)$	$(1)^2-(2)$
Ex. 1	1.0	1.75	-1.16667	-10.75	42.0	40.4444	-40.6389	4.22917
Ex. 2	1.0	2.5	7.6667	36.5	-203	-130.555	261.778	-1.41667
	(8)	(9)	(10)	(11)	TEST	(12)	(13)	
	(1)(2)-(3)	(6)(7)-(8) ²	$\frac{(5)}{(9)}$	$-(10)^2(5)$	$\left\{ \begin{array}{l} 1+(11)>0 \\ 1+(11)<0 \end{array} \right.$	$\left\{ \begin{array}{l} [1+(11)]^{1/2} \\ [-11]^{1/2} \end{array} \right.$	$\left\{ \begin{array}{l} \{(9)[1+(12)]\}^{1/3} \\ 0.186 \\ (12)+0.2 \end{array} \right.$	
	8.70833	-247.704	.163277	-1.07822	<0	1.03838	0.150196	
	-17.3333	-671.296	.194482	4.93801	>0	2.4368	-13.2137	
	(14)	(15)	(16)	TEST	(17)	(18)	(19)	(20)
	$\frac{(5)}{(13)}$	$\frac{1}{2}[(14)-(13)]$	$\frac{(15)}{(13)}$	$\left\{ \begin{array}{l} (16)>0 \\ (16)<0 \end{array} \right.$	$\left\{ \begin{array}{l} [(16)]^{1/2} \\ [-(16)]^{1/2} \end{array} \right.$	$2(1)(16)+(8)$	$\frac{(18)}{(17)}$	$2(7)-(15)$
	$\pm[0.75(5)]^{1/2}$ (Takes opp. sign to (9))	$(14)[1+(13)]$	$(15)+(7)$			As for (16)>0		
	5.50756	6.33477	10.5639	>0	3.25022	30.88	9.5009	2.12357
	-9.88031	1.6667	.25003	>0	0.50003	-8.9998	-17.9985	-4.50004

DATA SHEET-17

(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)
				Real or complex roots			
$2(1)(17)-(19)$	$[(20)-(21)]^{1/2}$	$[(20)+(21)]^{1/2}$	\longrightarrow	$(17)-(1) \pm (22)$	$-(17)-(1) \pm (23)$		
				Complex roots			
$2(1)(17)+(19)$	$[(20)^2+(21)^2]^{1/2}$	$\{\frac{1}{2}[(20)+(22)]\}^{1/2}$	$\frac{(21)}{2(23)}$	$(23)-(1) \pm [(24)-(17)]j$	$-(23)-(1) \pm [(24)+(17)]j$		
1.87487	.4987	1.9996		1.9989	1.0015	-3.0006	-6.9998
20.4987	4.99997j	3.99984		$[-1.99997 \pm 4.99997j]$		0.99981	-6.99987

Instructions for special cases

These cases are unlikely to occur in practice.

(i) When the magnitude of $(16)/(15)$ is less than about 0.02 and $1 + (11) < 0$ the accuracy of the results may not be sufficient, and it may be advisable to obtain (15) more accurately, using the fact that it should be a root of the equation $4x^3 - 3(5)x + (9) = 0$. For the explanation of this see special case instruction (i) of the cubic equation solution in which E corresponds to (15) here.

(ii) If $(9) = 0$ place 0 in column (15) and continue with columns (16) to (28).

(iii) If $(16) - (17) = 0$ use the following different formulæ:

$$(18) = (6) + 4(15)[(2) + (15)], (20) = -3(15).$$

Then if $(18) \geq 0$ put $(21) = (18)^{1/2}$ and continue using the upper formulæ in columns (22) to (28); if $(18) < 0$ put $(21) = [-(18)]^{1/2}$, and continue using the lower formulæ.

Note: See the note following the cubic equation solution.

TABLE II Solution of $a_0x^3 + a_1x^2 + a_2x + a_3 = 0$

EXAMPLES: 1. $x^3 - 6x^2 - 9x + 14 = 0$

(roots 1, -2, 7)

2. $x^3 + 8x^2 + 57x + 90 = 0$

(roots -2, -3 ± 6j)

	(A)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Column Heading	$\frac{1}{a_0}$	$a_1(A)$	$a_2(A)$	$a_3(A)$	$\frac{1}{2}(1)$	$(4)^2$	$(5)(4)$	$\frac{1}{2}(2)-(5)$	$\frac{1}{2}[(3)-(4)(2)+2(6)]$
Ex. 1	1	-6	-9	14	-2	4	-8	-7	-10
Ex. 2	1	8	57	90	2.66667	7.11113	18.963	11.8889	-12.0371

(9)	(10)	TEST	(11)	(12)	(13)
$\frac{(7)}{(8)}$	$(9)^2(7)$	$1 + (10) > 0$	$[1 + (10)]^{1/2}$	$\{(8)[1 + (11)]\}^{1/2}$	$\frac{(7)}{(12)}$
		$1 + (10) < 0$	$[-(10)]^{1/2}$	$\pm [-3(7)]^{1/2}$ (Takes opp. sign to (8))	$\frac{0.186}{(11)+0.2}$
0.7	-3.43	< 0	1.85203	4.58258	.0906419
-0.987688	11.598	> 0	3.54936	-3.79745	-3.13076

(14) Root	(15)	(16)	(17)	TEST	(18)	(19)	(20)
$\frac{(13)-(12)-(4)}{(12)[1+(13)]-(4)}$	(3)	(1)+(14)	(16)^2+4(15)	$(17) > 0$	$[(17)]^{1/2}$	Real roots $\frac{1}{2}[(18)-(16)]$	$-\frac{1}{2}[(18)+(16)]$
	(14)			$(17) < 0$	$[-(17)]^{1/2}$	Complex roots $-\frac{1}{2}[(16) \pm (18)]j$	
6.99795	2.00059	.99795	8.99826	> 0	2.99971	1.00083	-1.99883
-1.99998	-45.0005	6.00002	-144.002	< 0	12.0001	$[-3.00001 \pm 6.00005]j$	

Instructions for special cases

These cases are unlikely to occur in practice.

(i) When (14) is very small so that $(14)/(1)$ is less than about 0.01 with $1 + (10) < 0$ the accuracy of the results may not be sufficient, since the expression $E = (12)[1 + (13)]$ is an approximation, subject to a maximum error of less than 0.1%. It might be advisable to obtain a more accurate value of the root (14) by one of the well-known methods, then continue with columns (15) to (20) as shown.

(ii) If $(8) = 0$, a root of the equation $= -\frac{1}{2}(1)$. Place $-\frac{1}{2}(1)$ in col. (14) and continue with cols. (15) to (20) as shown.

Note: In some equations occurring in practice the coefficients increase or decrease sharply from a_0 to a_1 , a_1 to a_2 etc., and the solution is made easier by a suitable substitution $x = \lambda y$, where λ is a constant such that the equation in y has coefficients of about the same magnitude.

Mechanical computer provides air speed

True air speed, Mach number and miles flown, from pressure and temperature

TRUE AIR SPEED IN THE RANGE 150 TO 600 knots, to an accuracy of $\pm 1\%$, Mach number from 0.3 to 1.2 with an accuracy of ± 0.01 , and air miles flown to ± 6 nautical miles, are obtainable with a new 'true air speed unit' (type 6B/3013) developed by Kelvin Hughes. This device, which weighs 27 lb only, has been developed as an air mileage unit for the V-bombers and other modern aircraft, and has undergone extensive flight testing.

General operation

True air speed is a function of pitot and static pressures, and air stream temperature, and a mechanical com-

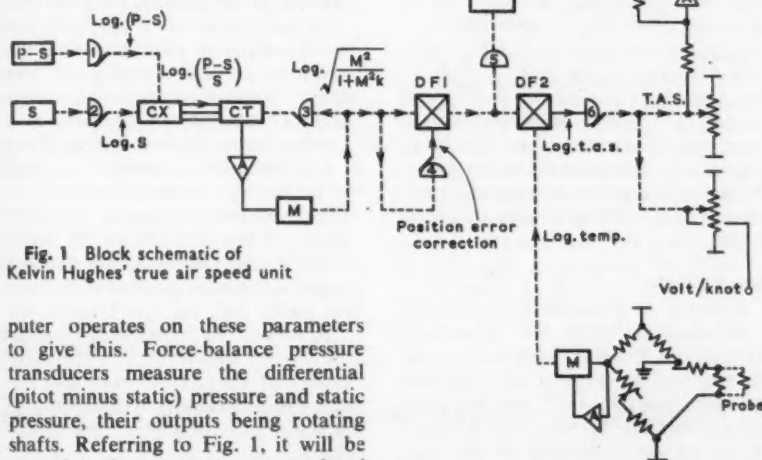


Fig. 1 Block schematic of Kelvin Hughes' true air speed unit

puter operates on these parameters to give this. Force-balance pressure transducers measure the differential (pitot minus static) pressure and static pressure, their outputs being rotating shafts. Referring to Fig. 1, it will be seen that these outputs are rendered logarithmic by differential cams 1 and 2, the log cams being connected mechanically to a differential synchro, CX. The rotor of the synchro is driven by the pressure differential and the stator by the static pressure. The synchro feeds the stator of the control transformer synchro, CT, the signal induced in the latter's rotor being amplified and fed back via a servo-motor and cam 3 to null that rotor.

From here the modified signal is fed to mechanical differential, DF1, driving one side directly and the other side through cam 4. The latter is cut to suit the probe-position error for that particular aircraft, and the output is thus corrected.

This last value is separated into two identical functions: one is converted to Mach number by cam 5; the other drives one side of the mechanical differential DF2. A function of indicated stagnation temperature is fed into the other side of DF2, this value having been obtained from a servo-controlled Wheatstone bridge with a temperature bulb in one arm. The final drive from

the beam, the other end carrying a nut running in a micrometer lead-screw. Beam deflexion is sensed by an inductive pick-off. In the balance position there is no output but, on deflexion, the voltage in one winding will increase and that in the other decrease. The output signal across the secondary winding is amplified and used to energize the control phase of a size 11 motor.

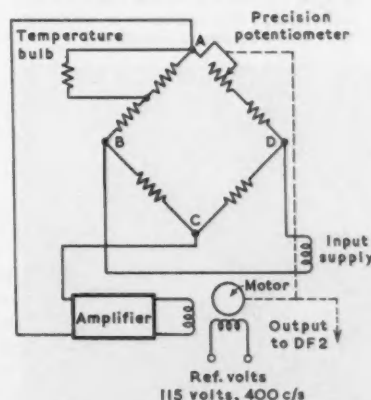
The motor drives the leadscrew, causing the nut to vary the tension of the spring in such a direction as to balance out the deflexion of the capsule.

These force-balance units are temperature-compensated with the aid of bi-metal strips whose movement is applied to the beam through a spring. The spring applies a restoring force to combat any movement due to a change in temperature. A zero-adjusting spring, operating much as the temperature compensator, facilitates calibration, and reversing micro-switches safeguard the unit if excessive pressure is applied. These switches apply a voltage such as to oppose the normal direction of motor-rotation.

The temperature bridge

The function for temperature is obtained from the self-balancing Wheatstone bridge of Fig. 2. One arm

Fig. 2 The temperature parameter is obtained from a self-balancing bridge



DF2 is linear to the logarithm of true air speed and is reduced to t.a.s. by cam 6.

Air miles flown is obtained by integrating the t.a.s. output with an a.c. tachometer operating a Veeder counter.

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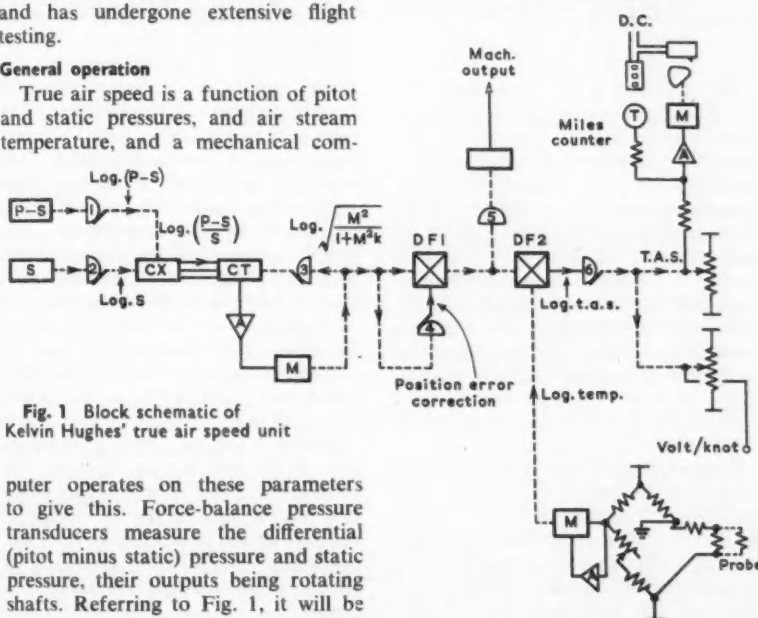


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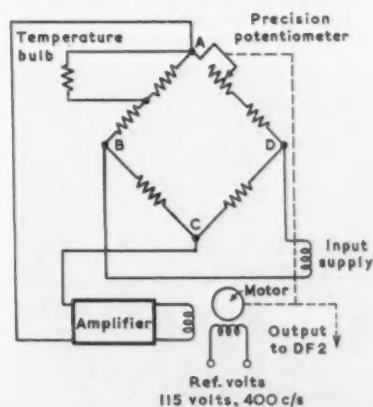
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consists of a temperature bulb, together with a shunt and series resistance, the other arms being formed by a motor-driven potentiometer, and conventional resistor arms. The bridge is energized across BD, and an output is obtained from AC when a change in temperature affecting the resistance of the bulb unbalances the bridge.

Any unbalance signal is amplified and caused to power a two-phase motor which drives the potentiometer and brings the bridge back to balance. The resistance values of the bridge are so selected that the potentiometer rotates in accordance with the logarithm of temperature, and this rotation is fed to the differential DF2. The

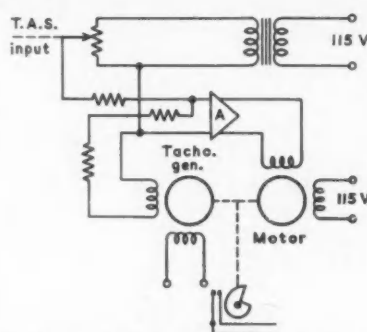


Fig. 3 Air miles flown from t.a.s.: a tacho-Velodyne operating a counter

latter provides a mechanical t.a.s. output via cam 6 (Fig. 1).

Air mileage circuit

As described above, air miles flown is obtained by integrating the true air speed output. The mechanical t.a.s. output drives the wiper of a potentiometer (Fig. 3), the voltage on the wiper being amplified and fed to the control phase of an inductance motor. The motor drives an accurate tachogenerator whose output is used to back-off the potentiometer input to the amplifier. The motor is, therefore, rotating at a speed which is a linear function of t.a.s. A Tufnol cam driven by the motor's shaft operates make and break contacts which control the operation of a Veeder counter indicating air miles flown.

CONTROL IN ACTION

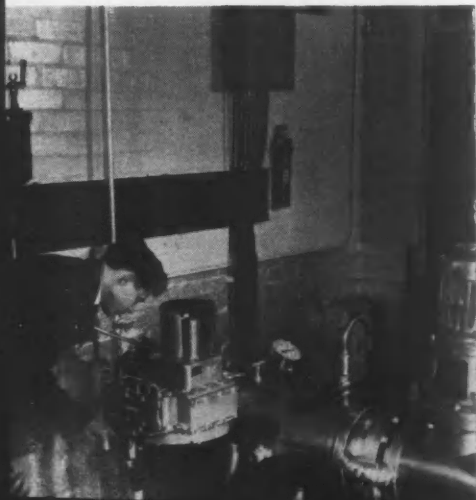
Viscosity control at Mobil Oil

Smiths controller gives 3-4% savings in blend costs

ALTHOUGH IT IS USUAL TO TEST THE viscosity of liquids in the laboratory, this is time-consuming and, if it is a continuous process which is under investigation, any number of changes in viscosity may occur while the test is being carried out. Furthermore, a close check must be kept on temperature during the test, and the final results are not uncommonly somewhat imprecise.

One continuous process in the petroleum industry where this problem applies, is the blending of black oil with gas oil to produce fuel oil. Although gas oil is expensive, it is the normal practice to introduce more of it into the blend than is strictly necessary in order to ensure that the product never falls below the guaranteed standard.

Fig. 1 Smiths viscosity controller at Ellesmere Port, Cheshire, Ocean Terminal of the Mobil Oil Co. The standard sample is contained in the vessel on the wall (left). The operator is collecting an overflow of sample oil



In an attempt to overcome this costly problem, Mobil Oil approached Frank Ramsay Ltd. and Smiths Industrial Instrument Division for a viscosity controller capable of monitoring the output of a blending unit. They required a controller capable of maintaining viscosity to $\pm 2\%$, and having a response time not longer than 30 s. Smiths were able to improve upon this specification, their instrument being capable of detecting a 1% change and having a 25-s response time.

User's tribute

CONTROL understands that prototype controllers at Mobil Oil's Ellesmere Port Ocean Terminal were so successful that the oil company said: 'Savings of approximately 3-4% per ton may be achieved on the cost of making a blend by the utilization of the viscosity controller. Such savings would be achieved by the use of reduced quantities of higher-cost cutter stock in the blend. Savings in capital expenditure and operating costs would accrue.'

Two viscometers

The Smiths in-line viscosity controller employs two viscometers, the viscosity of a sample from a pump line being continuously balanced against the viscosity of a standard. The viscosity of each sample is measured by a rotating-cup viscometer whose output torque acts upon a balance arm. Both viscometers run in a water bath and are driven at the same speed by an electric motor. The laboratory-

tested sample in its viscometer is at the temperature of the bath, and the sample from line also attains that temperature as it passes through a heat exchanger immersed in the bath. The precise temperature of the bath is not important, as the viscosity of each sample is measured at the same temperature although, in practice, it is increased when dealing with products of high viscosity, in order to reduce the torque to a reasonable value.

Each viscometer runs at the same speed and temperature as the other, so that if the viscosity of the standard sample is the same as that of the product under test, the two torques will be equal and the balance arm will be in a state of equilibrium. A change in viscosity of the product from line, will cause the balance arm to move and so operate a microswitch or a pneumatic control.

Operating principle

The cutaway diagram Fig. 2 shows the principle of operation. A standard sample of the desired viscosity is introduced to the sample viscometer through pipe 1. The sample passes to the lower bearing spigot and cross passages, and from there to the space around the outside of the rotating drum. Finally, it passes through the peripheral holes drilled around the mid-point and fills the annular space between the rotating drum and the measuring drum.

The oil from the blending line, whose viscosity is to be controlled, enters the strainer 2, through the pipe 3, and thence flows through the pipe

4 to a pump. The strainer is of small capacity as a large capacity could unduly delay the signal that indicates a change in viscosity. The pump 5 isolates the apparatus from line pressure. The line-oil passes through the pump, enters the heat exchanger via pipe 6, then flows through the connexion 7 into the in-line viscometer.

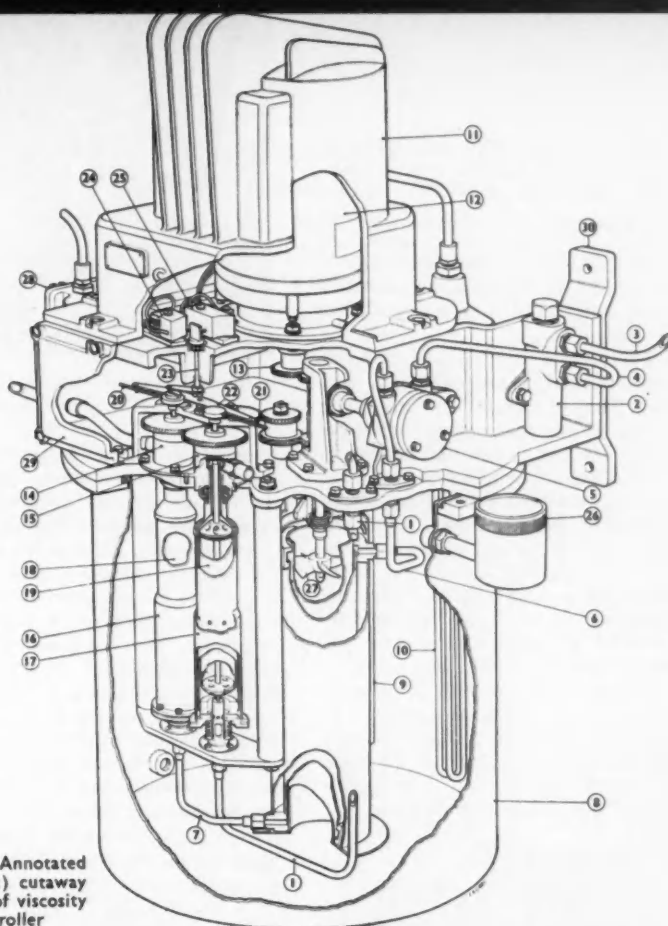
The heat exchanger, which raises the temperature of the oil from the line to that of the standard sample in approximately five seconds, consists basically of two concentric metal sleeves. Oil from the line is forced through the annular space between the sleeves, whilst water is circulated by means of the impeller 27, through the inner sleeve and the water jacket surrounding the outer sleeve.

The temperature of the water bath 8 is maintained by a thermostat 9 governing a heating element 10. The exact temperature is not important, and is set to a value that ensures that the viscosity of the line sample, and hence the torque produced at the viscometers, is not too high. The water bath may be topped-up through the filling cap 26.

The controller is of flameproof construction. The top cover 11 is cut away in the diagram to show the driving motor 12. This drives the spur wheel 13, which in turn drives the pump 5 and the rotating outer sleeves of the viscometers 14 and 15.

The standard and sample oils enter the viscometers, and rotation of the outer cylinders 16 and 17 causes a viscous drag on the inner, or measuring, cylinders 18 and 19. This torque is applied to the arms 20 and 21, which act upon the balance arm 22. Any motion of the balance arm is trans-

Fig. 2 Annotated (see text) cutaway diagram of viscosity controller



mitted through the shaft 23 to operate the microswitches 24 and 25.

Pneumatic controller

The viscosity controller in Fig. 2 is a simple on-off electrical type whose microswitches operate relays to control a motorized valve in the blending unit. A requirement for pneumatic proportionate control has led Smiths to design what they say is a highly-

satisfactory prototype pneumatic controller which is capable of detecting a change in viscosity of $\pm 0.5\%$. CONTROL understands that this improved sensitivity is due to the fact that less torque is required to operate a pneumatic control than to operate microswitches. In the pneumatic controller the microswitches are replaced by a drive taken from the balance unit by bevel wheels.

CONTROL IN ACTION

Automatic mine-winder control

Coal handled automatically in No. 2 Shaft of N.C.B.'s Warsop Colliery

IN THE 1421-FT DEEP NO. 2 SHAFT AT Warsop Colliery (No. 3 Area, N.C.B. East Midlands Division) an over-hung armature by A.E.I. Heavy Plant Division is used in a recently-installed tower-mounted friction winder. This is a skip winder, handling coal exclusively, and operation from the arrival of the coal train at the tipping station underground to discharging at the top of the shaft, can be automatic. Operation depends on the flow of coal from the face. The arrival of the skip at the underground filling station operates a magnetic proximity switch which begins the sequence of operations by

loading coal into the skip and then switches the flow of coal from the tipplers to the appropriate measuring pockets.

The control system permits automatic winding to be carried out continuously, and safeguards are provided so that, in the event of interruption in an emergency, the cycle of operations must be completed manually before automatic winding can be resumed. With the normal flow of coal, the skip is moved when it contains eight tons of coal. If, however, the supply of coal from the working is reduced, the arrangement is such that

after a pre-determined interval the winding cycle is initiated. Thus, in spite of a slow flow of coal from the face, an empty skip is frequently available at the bottom of the shaft. The operation is completely interlocked and must take place in the correct sequence before the winding cycle can be started.

The winder is of the Ward-Leonard type with closed-loop control, employing the Lamex scheme, in which a laminated-yoke exciter is used to supply the fields of the generators of the Ward-Leonard system. The exciter fields are in turn supplied from a

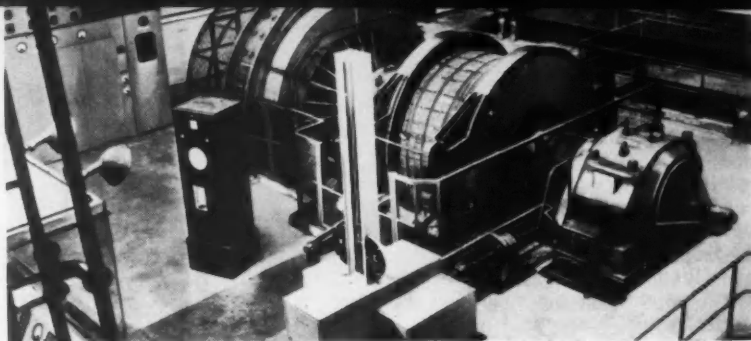
valve-controlled flux-resetting magnetic amplifier, giving speed control with overriding current or torque limits, acceleration and retardation limits, and peak-power limit. As already mentioned, the winder can be arranged for automatic operation, being interlocked with the skip plant as appropriate.

The winder can also be operated under manual or semi-automatic control. Manual control by the driver is through control levers in the winder room. The driver operates the winder in response to audible and visual signals received from the banksman, and any speed can be chosen below the maximum set by the control system. The retardation of the winder, as the conveyances approach the terminal points of the shaft, is automatically achieved by means of a cam-gear driven from the winder drum.

Semi-automatic control is by push-button from the banksman's platform; no driver is needed, and each wind is initiated by the banksman. The control system is set up so that the winder follows the designed speed cycle.

Fully-automatic control

Automatic control is available when the winder is interlocked with the skip plant. Each cycle is initiated when (a) the skip at the bottom of the pit is filled and the filling-chute retracted, and (b) the skip at the surface is empty and the hopper guillotine-door is shut. The winding sequence is thus initiated automatically, without the



This A.E.I. motor rated at 1638/2120 h.p., 77.3 rev/min., drives the automatically-controlled skip winder at Warsop No. 2

intervention of a driver or other operator, and continues until it is deliberately stopped by operation of appropriate control switches.

Three special features are provided for safe and efficient operation. First, if the flow of coal which controls the skip plant operation is reduced, an automatic 'wind' is initiated after an interval, irrespective of whether the skip at the pit-bottom is fully loaded or not. Thus an empty skip is available at regular intervals at the pit bottom. The second feature ensures that the minimum time is wasted if the hopper into which the ascending skip is to be unloaded, is full. The interlocking system is such that, in this event, the skip is stopped just short of the discharge position and is started automatically to complete the wind as soon as the receiving hopper is sufficiently empty to receive the load. The third feature ensures that any creep between the ropes and the driving pulley is automatically corrected at the end of each wind. An

automatic creep-correcting unit is provided which adjusts the control devices, e.g. depth indicator, cam gear, and automatic contrivance (Lilly controller) whenever the position of these devices does not correspond with the skip position. By means of switches on the headgear and on one of these control devices, the creep corrector determines when such misalignment has occurred and adjusts the position of the control devices. This is done by means of a motor driving a differential-gear unit which is positioned in the drive between the driver and the control devices. This creep corrector is interlocked, so that it is operative only when the winder is stationary and the mechanical brakes applied.

The whole installation was planned in close co-operation with the suppliers of the skip plant equipment which was manufactured in Germany by Guttehoffnungshutte and Siemens-Halske. In order to comply with British regulations, a number of flame-proof units were provided by A.E.I.

LOOKING AHEAD

Unless otherwise indicated, all events take place in London. B.C.S. British Computer Society, Brit. I.R.E. British Institution of Radio Engineers, I.E.E. Institution of Electrical Engineers, R.Ae.S. Royal Aeronautical Society, S.I.T. Society of Instrument Technology, I.Mech.E. Institution of Mechanical Engineers.

WEDNESDAY 13 APRIL
Guided Weapon Control by F. R. J. Spearman. 6.30 p.m. Brit.I.R.E.

Informal Evening on Novel Pneumatic Devices and Applications. The Northampton College, E.C.1. 6 p.m. S.I.T.

MONDAY 25—FRIDAY 29 APRIL
2nd European Fluid Power Conference and 1st International Compressed Air and Hydraulics Exhibition, Empire Hall, Olympia.

MONDAY 25—SATURDAY 30 APRIL
Production Exhibition, National Hall, Olympia.

TUESDAY 26 APRIL
An Experimental Transistor-controlled Component Selection and Testing Machine by T. C. Cardwell, J. R. W. Smith and G. H. King. 5.30 p.m. I.E.E.

Control Section Annual General Meeting. 6.15 p.m. Some Recent Advances in Industrial Electrical Control Techniques. S.I.T.

WEDNESDAY 27 APRIL—FRIDAY 6 MAY
Fuel Efficiency Exhibition, Olympia.

THURSDAY 28 APRIL
Discussion on Education Committee's Report on The Education and Training of the Professional Radio and Electronics Engineer. 6.30 p.m. Brit.I.R.E.

TUESDAY 3 MAY
Discussion on Teaching and Learning Machines. Opened by C. E. G. Bailey. 5.30 p.m. I.E.E.

TUESDAY 3—FRIDAY 13 MAY 1960
Mechanical Handling Exhibition and Convention. Earls Court

WEDNESDAY 4 MAY
Computer Controlled Television Displays for Flight Simulators by J. N. Naish. 6.30 p.m. Brit.I.R.E.

FRIDAY 6 MAY
Discussion on Methods of Recording Measurements—Digital or Analogue. Opened by W. J. Perkins. 6 p.m. I.E.E.

TUESDAY 10 MAY
Start of a course of 6 lectures to be held on Tuesdays on Ferrites—their Principles and Applications by J. Roberts. Norwood Technical College. 7 p.m.

WEDNESDAY 11 MAY
Radio Guidance in the Automatic Landing of Aircraft by J. Shayler. 6.30 p.m. Brit.I.R.E.
Sixth Conference of Standards Engineers, Connaught Rooms, London. Organized by British Standards Institution jointly with Institution of Production Engineers. Applications for tickets: Secretariat, I.P.E./B.S.I. Committee, British Standards House, 2 Park Street, London, W.1.

Data Processing Section Annual General Meeting. 6.15 p.m. S.I.T.
A Recording Stereocomparator by A. E. Adams. 7 p.m. S.I.T.

WEDNESDAY 18 MAY
Symposium on Electronic Equipment Reliability. Sessions at 10.30 a.m., 2.30 p.m. and 5.00 p.m. Registration form from I.E.E.

MONDAY 23—SATURDAY 28 MAY
Instruments, Electronics and Automation Exhibition, Olympia.

TUESDAY 24 MAY
S.I.T. Annual General Meeting. 6 p.m. Presidential Address. 7 p.m. R. S. Medlock.

WEDNESDAY 25 MAY
Discussion on New Semiconductor Devices and their possible Applications. Opened by A. F. Gibson and G. King. 5.30 p.m. I.E.E.

WEDNESDAY 1—FRIDAY 3 JUNE
Instrument Society of America's 6th National Symposium on Instrumental Methods of Analysis.

WEDNESDAY 8—FRIDAY 10 JUNE
3rd Symposium on Gas Chromatography, Edinburgh. Details: L. Brealey, Boots Pure Drug Co., Nottingham.

FRIDAY 10—SUNDAY 26 JUNE
British Exhibition, Coliseum, New York.

WEDNESDAY 15—WEDNESDAY 29 JUNE
7th International Nuclear Congress and Exhibition on Electronics, Rome. Details: Secretariat, 14 Via della Srofa.

SATURDAY 18—WEDNESDAY 29 JUNE
S.I.M.A. Exhibition of British Scientific Instruments, Moscow.

FRIDAY 24 JUNE—FRIDAY 8 JULY
International Machine Tool Exhibition, London.

MONDAY 27 JUNE—WEDNESDAY 6 JULY
Moscow Congress for Automatic Control. Applications: Hon. Sec. Group A, B.C.A.C., c/o I.Mech.E.

A monthly review—under basic headings—of the latest control engineering developments for all industries; specially edited for busy technical management, plant and production engineers, chemical engineers, etc., who are not specialized in instrument and control systems

IDEAS APPLIED . . .

. . . to TEMPERATURE

Transistor amplifier for thermocouple signals*

I. C. HUTCHEON
George Kent Ltd., Luton

The measurement of thermocouple signals is frequently complicated by the presence of comparatively large voltages between the thermocouple and earth, either direct or, more com-

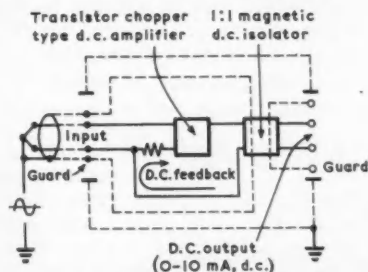


Fig. 1 Amplifier, showing guard screen monly, alternating at line frequency. This occurs particularly in electric furnace and similar applications, where voltages as high as 250 V are encountered on occasion.

One way in which this difficulty can be overcome is shown in Fig. 1. A small transistor chopper-type d.c. amplifier is totally enclosed within a 'guard' screen connected to the source. The amplifier output is passed through a 1:1 magnetic type of d.c. isolator whose gain is accurate within $\pm 0.1\%$, and the whole assembly is mounted in an earthed outer case for safety.

*See also Hutcheon, I. C., and Summers, D., 'A low-drift transistor chopper-type d.c. amplifier with high gain and large dynamic range.' Paper No. 3227, March 1960, I.E.E.

Fig. 2 shows a practical amplifier based on this principle. The transistor input chopper operates at 200 c/s, and the transistor itself is mounted in a small oven, as shown in Fig. 3. This holds its temperature stable within $\pm 2^\circ\text{C}$ and assists in keeping the drift of the whole amplifier below $\pm 10 \mu\text{V}$ and $\pm 4 \text{ m}\mu\text{A}$ in ambient temperatures between 0 and 50°C .

Forward gain of the amplifier is such that the full output-change of 10 mA is provided by a change of input signal not greater than 0.5 μV and 0.5 $\text{m}\mu\text{A}$. Overall d.c. feedback can therefore be applied to give a performance which is limited only by the drift figures. For example, a 10 mV signal can be amplified to 10 mA with an accuracy of $\pm 0.1\%$ prior to the isolator, and $\pm 0.2\%$ after it.

Demodulation within the amplifier

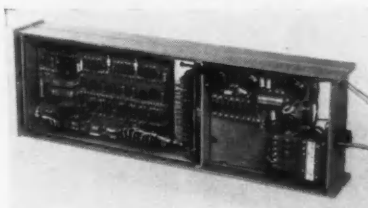


Fig. 2 Underside of amplifier chassis is performed at a low signal-level, and the demodulated output is smoothed by a feedback integrator. This allows the system to handle relatively large changes of input-signal without saturation, minimizes the effect of series pick-up, and maximizes the response.

Common-mode a.c. or d.c. voltages

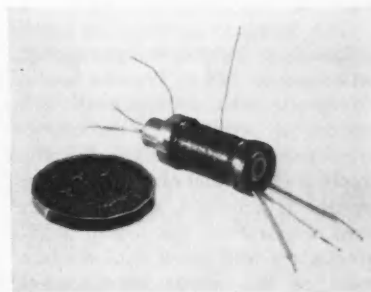


Fig. 3 Transistor-stabilizing oven

up to 300 V at the input have no effect on the accuracy, the response of the output to large input signals is at a rate of 50 mA/s, and the load may have any value between 0 and $2 \text{ k}\Omega$ without affecting the output current.

. . . to PRESSURE

Due to problems of phasing, and the fact that harmonics are invariably present in the output, it is often difficult to use an a.c. energized inductive transducer directly with a conventional electronic self-balancing potentiometric recorder-controller.

An inductive transducer can, however, be used very successfully with a chart recorder, which has been modified as follows. The slide-wire resistance unit, normally driven by a two-phase motor, is replaced by a micrometer-screw-operated inductive-transducer, the electrical and mechanical characteristics of which are identical to those of the external head. The displacement of the armature of the built-in transducer is 0.05 in. for full-

IDEAS APPLIED . . .

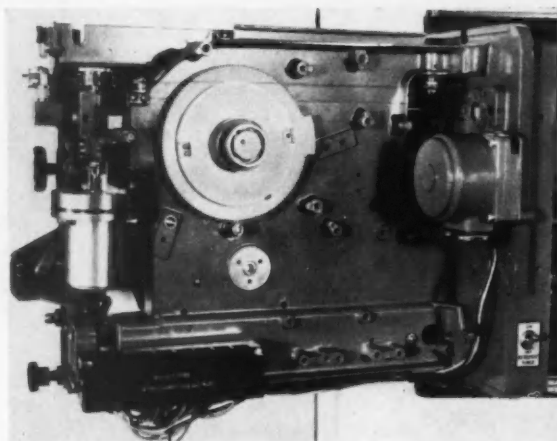
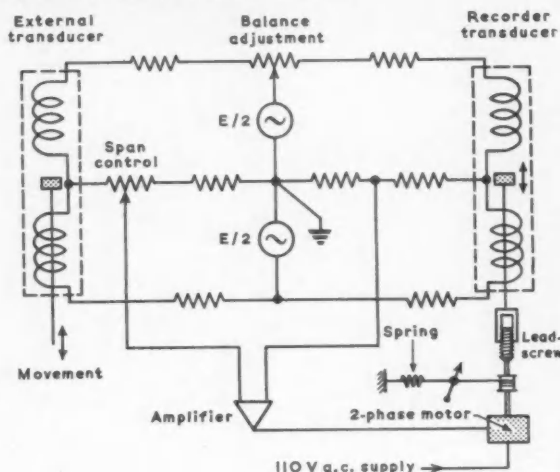


Fig. 1 (left) Basic self-balancing circuit

Fig. 2 (right) Modified recorder

scale travel of the recorder pen. The external pressure-detecting head must have the same armature-travel.

The circuit is arranged as a self-balancing inductance-bridge recorder, as shown in Fig. 1. Pressure applied to the external transducer causes it to be out of balance with the internal transducer, and a voltage therefore appears about the earth point. This voltage is amplified, and fed to the control phase of the motor, which rotates the lead screw until displacement of the internal transducer is equal to that of the outer. The circuit is then in balance, and consequently there is no voltage at the amplifier. The rotation of the lead screw in balancing the system winds or unwinds a cord wrapped round the small drum attached to it. The indicator and recording head are motivated by the movement of the cord. This system is distinguished by a high degree of repeatability and stability, due to the balancing of inductance changes of one sense in the detecting element by inductance changes of the opposite sense in the recorder-transducer.

A sharp balance-point is obtained, and linearity and repeatability are between 0.1 and 0.2%. Input-voltage variations of 180-240 V, and frequency-variations of 45-55 c/s, produce no significant changes in reading.

The system is, of course, not limited to the measurement of pressure. A distinguishing feature is that if a multi-point recorder is used, load, displacement, level, etc., as well as fluid-pressure, can be recorded on one chart, and the control facilities associated with the recorder can be fully utilized. The work has been a joint effort by

Salford Electrical Instruments Ltd. and Honeywell Controls Ltd. The recorder illustrated in Fig. 2 is the latter's 'Elektronik'.

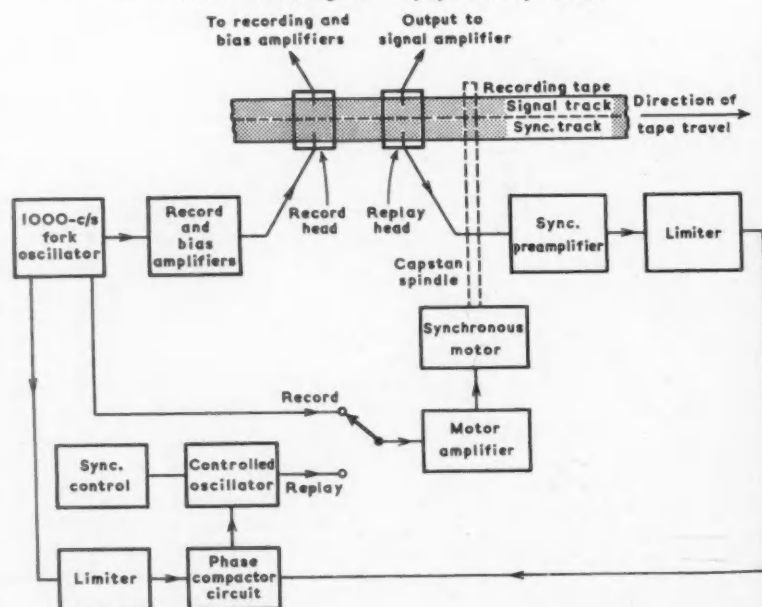
. . . to SPEED

A facsimile tape recorder, required to store complex wide-band signals, must have the tape speed during replay equal to the speed of tape during recording. A method of achieving such synchronization is used in the D-944 recorder of Muirhead (Fig. 1).

During recording, a very stable 1000 c/s signal, derived from a tuning fork, is recorded on a synchronizing track occupying half of the tape.

During replay this synchronizing signal is taken off by the playback head, amplified, and passed to a phase-comparator circuit which is connected to the stable oscillator. The synchronous motor which drives the tape is supplied with power by an oscillator controlled by the phase comparator circuit. Hence, if tape stretch (e.g. due to temperature), causes a variation in the frequency of the synchronizing signal, the phase-comparator circuit applies a signal, proportional to the difference, through an amplifier to the synchronous motor, and regulates the replay speed so that it follows more or less exactly the speed of tape during recording.

Fig. 1 Synchronizing circuit of facsimile recorder; normal recording and replay circuitry omitted



NEWS ROUND-UP

from the world of control

BUSINESS

Elec.-Mech. tie-ups

Simon evade E.M.I.

E.M.I. have been thwarted once again in their attempts to acquire increased mechanical know-how by purchasing an existing company of general engineers. As reported in February, they were beaten to the post in the race for Lancashire Dynamo by the Metal Industries Group, and, last month, *CONTROL* reported E.M.I.'s strong bid for Henry Simon. In the event, Henry Simon evaded take-over by merging with its partner in control of Simon Engineering, Simon-Carves. However, there is little doubt that E.M.I. will eventually succeed in marrying its enormous strength in electronics with the mechanical experience necessary for systems engineering.

Solartron-John Brown

This trend towards the merging of electronic and mechanical firms is exemplified by the recent formation of a new company, Solartron-John Brown Automation Ltd. This company is owned jointly by John Brown and Co.—shipbuilders, civil and mechanical engineers, and Solartron—electronics, and has been formed to design and manufacture systems of automation for the manufacturing, distributive and consumer fields. It is understood that Solartron-John Brown Automation have the exploitation rights for the American Gumpertz automatic warehousing dispensing system in all countries outside America.

The Board of the new company consists of four John Brown men, Sir Norman Hulbert (Chairman), Eric Mensforth, Frank Simon, and R. J. Barclay, and two Solartron men, Bowman Scott and Eric Jones. It will be recalled that Firth Cleveland recently acquired a 53.125% interest in Solartron.

Winston goes American

The total shares of Winston Electronics (which were privately held) have been sold to The Dynamics Corporation of America, for cash plus a block of Dynamics' shares. Winston Electronics will continue to operate under its present management—F. Winston Reynolds (Chairman and Managing Director), Roger Laurence (Technical

Director) and Joseph Samuels (Works Director)—as a wholly-owned subsidiary of Dynamics. The British subsidiary is to be the European sales and manufacturing base for Dynamics' products, including their tropospheric scatter communications equipment.

To quote from Winston's statement: 'It is anticipated that Winston Electronics Ltd. will also in due course manufacture for the Continent of Europe within the Common Market area.' It looks as if The Dynamics Corporation does not intend to be squeezed out of a Europe which is all at sixes and sevens. It is likely that we may hear more of American companies using British and Continental firms as stepping stones to Europe.

A.E.I.'s year

Associated Electrical Industries sold goods worth £M208 last year and their report—the first since the completion of the re-organization which resulted in the disappearance of such well-known names as B.T.H., Metrovick and Sunvic—makes interesting reading. It appears that every £1 income is accounted for as follows: raw materials, 8s. 6d.; wages and salaries, 6s. 2d.; operating expenses, 3s. 9d.; depreciation, 6½d.; taxation 5½d.; profits retained, 2½d.; dividends, 4½d.

A.E.I.'s A.G.M., at which Lord Chandos will review the year, is to be held on April 21.

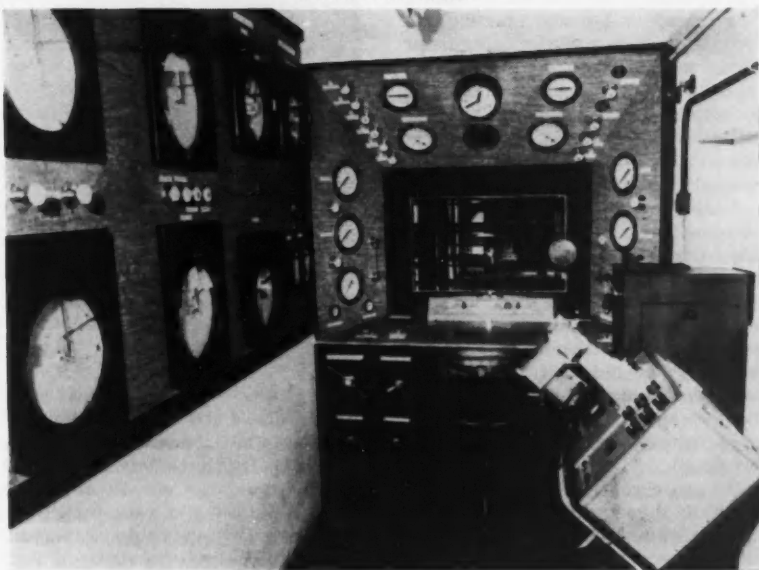
Blackburn's £264,000 orders

During the past eight months Blackburn Electronics have received orders worth more than £264,000. Dr. Harry Fuchs, Director and General Manager of the company, commented: '... I expect our order book to top £M1 per annum in three years time.' This encouraging result, after only one year's trading, seems to be due to increasing interest in data loggers, Blackburn Electronics' chief product. The U.K.A.E.A. have installed one at Harwell and have four more on order for Chapelcross; one has been ordered for use with the radio telescope at Jodrell Bank; one is being used for research into steel smelting by United Steel; one is on order for Reckitt & Colman's chemical production plant; and the College of Aeronautics, Cranfield, have ordered an equipment for research on structures.

Kent steer clear

The entire capacity of George Kent is being applied to industrial instrumentation, process control and mechanical meters now that their Steering Gear Division has been transferred to

TESTING AIRCRAFT VALVES. Saunders Valve's aircraft valve-testing rig at Hereford employs pneumatic instruments by Honeywell Controls for recording valve pressures and fluid-flow values



Cam Gears Ltd. Kent have manufactured steering gears for thirty years, supplying them to Cam Gears for the motor-car trade, and retain a 40% interest in that company. CONTROL understands that the growing complexity of the process control field has led Kent to undertake this rationalization.

Kamra now Standard

Seton Creaghe Engineering's parent company has changed its name from Kamra Investments Ltd. to Standard Industrial Group Ltd. This follows from Kamra's acquisition of an issuing house known as Standard Industrial Trust.

SPACE

Pioneer V's success

America's Pioneer V, the so-called Venus probe which was successfully released from the third stage of a Thor-Able launching rocket, fired from Cape Canaveral on March 11, is behaving much as expected. Apart from representing a rocket engineering feat of the highest magnitude, Pioneer V's greatest contribution looks like being in the field of radio communications, for it is hoped in July to communicate with the vehicle at distances of the somewhat staggering order of 50,000,000 miles. The vehicle was launched at 1 p.m. G.M.T., and at 1.25 p.m. G.M.T. a signal from Jodrell Bank caused fusion bolts connecting the payload to the rocket to burn out. This released Pioneer V from the vehicle's third stage and allowed it to continue in an orbit round the Sun between the orbits of Venus and Earth.

Instrumentation

The 26-in. diameter, 94.5-lb probe is expected to test the feasibility of long-range space communications, test a new method of measuring astronomical distances by triangulation and, by now conventional means, investigate radiation, count micro-meteorites, and determine the strength and direction of magnetic fields in space.

A high-energy radiation counter will measure 'hard' radiation, particularly that from the sun. This consists of six argon-filled cylinders around a seventh cylinder, radiation particles ionizing the gas in one or more cylinders and so producing impulses depending upon the energy of radiation. Total radiation flux is measured by an ionization chamber and a Geiger counter which are particularly sensitive to the medium energies.

The number and momentum of meteorite dust particles striking the probe is measured by a counter consisting of a diaphragm on the satel-

lite's surface and an internal microphone. Electrical impulses are thus produced for transmission to earth.

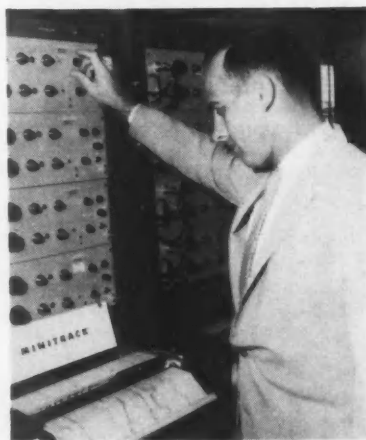
There is also an aspect indicator, a photo-cell device which triggers when looking directly at the sun. 'Fixes' obtained in this manner should give more meaning to the measurements of magnetic fields and radiation.

Communications

The satellite contains 'logic' units which transform the various instrument-sensing actions into signals for transmission to earth, and a command unit capable of initiating ten functions. The satellite has two transmitters, a 5-watt model which should transmit for about 25 min. a day until Pioneer V is a 'few million miles from earth,' and a 150-watt transmitter which is expected to take over at extreme ranges and operate for a few minutes a day in order to conserve the batteries. When that happens, the 5-watt transmitter will act as a booster for the 150-watt model. Silicon solar cells are employed in 'paddle-wheel' formation to charge the batteries powering the equipment.

Vanguard I still at it

On March 17, 1958, the American earth satellite, Vanguard I, was launched into orbit. Over two years later it is still in orbit, circling the earth every 134.04 min., and should remain in orbit for 200 years. Its 5-mW transmitter is still transmitting experimental data on 108.03 Mc/s,



The original Vanguard I earth satellite (born March 17, 1958) is still transmitting data to Minitrack stations such as this at Fort Myers, Florida

power being provided by six solar cells which 'may last indefinitely.' Vanguards II (launched February 17, 1959) and III (September 18, 1959) are also in orbit. This speaks very well for the solar cell and gives every hope of Pioneer V's making communications history.

NAVIGATION

Off-course alarm

The Palm Line shipping firm have installed an 'off-course alarm' in the *Ilorin Palm*. Developed by Sperry Gyroscope, this is a self-contained heading reference, quite independent of the ship's gyro-compass, which gives audible and visual indications if the vessel deviates from the desired course, in either direction, by more than a pre-determined amount.

As the device is expected to have an operating life of at least ten years under world-wide sea-going conditions, it is of simple and robust construction. It is powered by dry cells and based on a conventional liquid-filled magnetic compass. If the vessel deviates from the desired course, the magnet system of the compass closes a pair of electrical contacts mounted within the compass bowl.

PETROLEUM

Tank-gauging at Shell

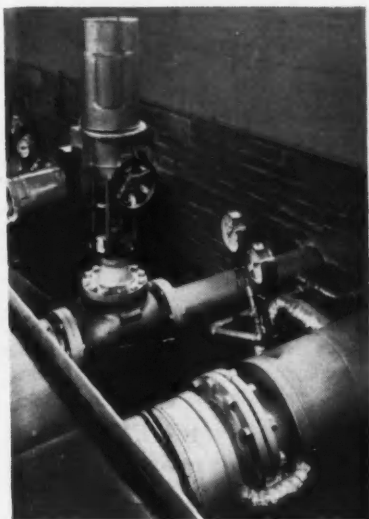
Shell Refining have ordered Gilbarco-Firth Cleveland automatic tank-contents gauges for 51 petroleum storage tanks at Stanlow and Shellhaven. Each tank will be equipped with a gauge connected to one of five Gilbarco remote reading receivers. Equipment for the remote reading of the average temperature of the tank contents is also to be installed.

Firth Cleveland Instruments manufacture the gauge and its ancillaries under licence from the American firm Gilbert and Barker, and CONTROL understand that in the U.S. the gauge has recorded tank contents to better than $\pm 1/16$ in. — $\pm 1/64$ in. in the laboratory. It reads liquid level in feet, inches and sixteenths regardless of specific gravity. It is power-actuated, so overcoming the friction effects common with the use of pulleys, and also obviating problems connected with the weight of the measuring element at high and low liquid levels.

Mobil Oil's blenders

The fuel oil blending units at Mobil Oil's Ellesmere Port Ocean Terminal (see *Control in Action*, page 136) are by Fisher Governor. The four in-line blending units use the principle of parallel metering of two fluid components and the establishment of equal pressures at the metering point. This method gives a high blend accuracy and requires no operating power.

Mobil Oil wanted an accurate blend at a high rate of flow, and Fisher modified their existing blending unit to meet this requirement. The units at Ellesmere Port have 10-in. heavy- and 6-in. light-oil arms with a 12-in. out-



Two arms of a Fisher blender at Mobil Oil's new Ellesmere Port Ocean Terminal. The electrically-operated metering valve is in the light-oil line

let. To ensure homogeneity of blend at the outlet, and before the controller's measuring point, a mechanical mixer has been installed. Each blender has a Smiths viscosity controller.

—ELECTRONICS— E.I.C. formed

The last vestiges of control by the Radio Industry Council of the capital-goods electronics industry, would appear to have been severed now that the Electronics Industry Council has been formed. There has been dissatisfaction with the R.I.C. among the industrial and professional electronics manufacturers for many years, it being felt that the Council was dominated by the radio and television receiver people. This suggested preponderance of interest in the domestic market was felt to make the R.I.C. unsuitable for acting as the official spokesman for the so-called professional electronics industry. In fact, the R.I.C. has been little concerned with the professional side of electronics for over a year—since the Electronic Engineering Association left that body.

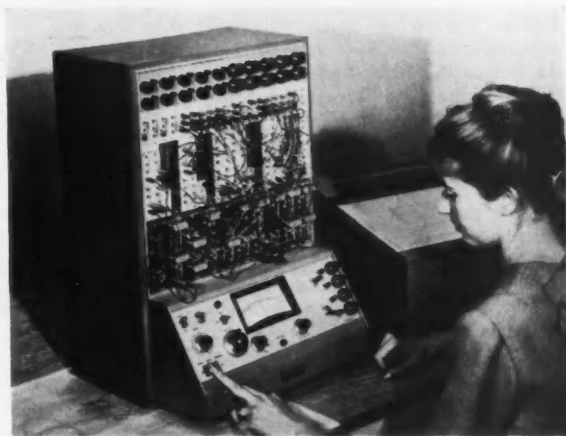
Now the E.E.A., the Radio and Electronic Component Manufacturers Federation and other (unnamed) bodies have set up the Electronics Industry Council. This is concerned with the manufacture in the U.K. of electronic components, apparatus and equipment except for those used in the broadcast radio and television receiving industry and for public telephone services. The E.I.C. covers electronic instruments, sound and television transmitters, radio communication, radar and radio navigational aids, computers,

industrial electronic control equipment, industrial television and the components used in such equipment. The E.I.C. is at 11 Green Street, London, W.1.

DATA PROCESSING Transistorized Pace

A new completely-transistorized analogue computer of small dimensions and low power consumption (60 W) was demonstrated recently by Electronic Associates, manufacturers of Pace. Available for sterling from the British subsidiary, Electronic Associates Ltd., the new TR10 computer has been designed more as a bench tool for the engineer or research worker than as a special-purpose facility. Its accuracy is understood to be 0.1%, and it is made up from operat-

Electronic Associates' Trio analogue computer may be used as a bench tool by the engineer or research worker



ing elements capable of the mathematical operations met in routine engineering work. Besides linear operational elements for addition, integration and multiplication by a constant, it has non-linear elements including quarter square multipliers, function generators and relay comparators. These are plugged into the chassis and are, therefore, easily replaceable. Problems are plugged in to the machine under the patch-panel system.

Short machine for Queen's

The Department of Aeronautics of Queen's University, Belfast, is now using a Short eight-amplifier computing unit for research into control systems. Together with complementary computing equipment designed and built by the University itself, the Short amplifiers are used in conjunction with other equipment to form a simple eight-amplifier analogue computer. The unit is based on the successful amplifier design employed in the Short Simlac machine. This is a printed-circuit amplifier of particular value in

special computing equipment. Its drift figure is 10 microvolts and it has a good dynamic response.

—STEEL— Bisra's programmed forge

The completely automatic forging of steel under a pre-calculated programme has just been successfully demonstrated—probably for the first time ever—by the British Iron and Steel Research Association in Sheffield.

Forging is carried out by a precision-controlled 200-ton press interlocked with a fast, remote-controlled, experimental manipulator capable of longitudinal, rotational and lifting movements. Electrical controls had been developed before this for both press and manipulator, and these ensure fast, accurate operation and syn-

chronize the movements of the two machines. During the forging process, both press and manipulator are controlled by a programme unit on which every detail of the schedule of forging operations has been set up. In this forging schedule, the upper and lower limits of the squeeze for every pass are given, the manipulator feed between strokes is selected and the manipulation necessary between passes is also stored. The control unit signals instructions to the press and to the manipulator in the appropriate sequence.

The finished forging in many respects exceeds the best current industrial standards for dimensional precision. However, the job may be accomplished twice as fast as it would by a highly-skilled forging crew. CONTROL understands that even faster working will be practicable shortly.

The forging schedules are calculated in advance, from a theory of the change in shape during forging which had been worked out at Bisra.

According to the Association, there are probably more forging presses on

order in this country than at any previous time; this development of automatic working, therefore, offers the forging industry a great opportunity to place itself ahead of foreign competition.

—ELECTRICITY—

Automatic generation

The South Western Electricity Board is to commission a remotely-controlled 3 MW turbo-alternator at Lynton. This, like the recently opened station at Princetown, South Devon (see *Control in Action*, January 1960), will be remotely-controlled from area headquarters at Bristol, by the Datofonic equipment of Sound Diffusion (Auto-thermatic) Ltd. Operating over normal Post Office lines, the Datofonic equipment will automatically call Bristol if a fault occurs or, alternatively, can be interrogated from Bristol. The system will include two remotely-controlled distribution substations in the Bristol telephone area (Filton Road and Cairns Road) and supervisory equipment will be installed at the Midsomer Norton distribution switch and transformer station.

All the new equipment will operate through the control panel already installed in the Bristol control room—the original panel could cater for twenty similar units. Control over circuit breakers, together with telemetering facilities, will be provided at Filton and Cairns Road. Midsomer Norton will automatically telephone Bristol if anything goes wrong, or may be interrogated from Bristol or from any other telephone in the national network.

—PNEUMATICS—

S.I.T.'s Informal Evening

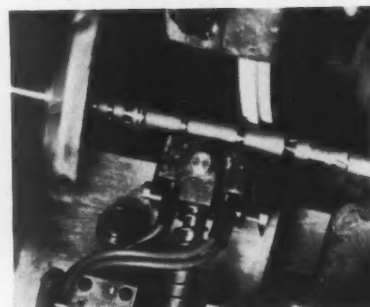
The Society of Instrument Technologists are to hold an Informal Evening on 'Novel Pneumatic Devices and Applications' at the Northampton College on April 13. It appears that there has been some criticism of certain papers because of a lack of appeal to many members. The pneumatics meeting will cover practical ground and, if this approach is successful, the S.I.T. hope to arrange a similar evening during the next session. The meeting will consist of short talks in which some device may be demonstrated, followed by a question period and discussion. The programme will cover novel arrangements of pneumatic servomotors, novel arrangements of electro-pneumatic transducers, control valves with electro-pneumatic transducers, novel pneumatic devices for heating and ventilating, the pneumatically-operated tube bore gauge, and pneumatic sine wave equipment.

—MACHINING—

Air-gauging at Sperry

The accurate machining called for in producing the Sperry electro-hydraulic servo valve was a problem to the company's production engineers, but it is vital that the spool shoulders should mate properly with the cylinder liner ports. This necessitated the separate grinding of each of the valve's four lands, with individual checking in a calibration fixture and subsequent re-grinding until perfect matching was achieved.

This time-consuming process has been overcome by their design of an air-gauging system, and its manufacture by Thomas Mercer, which enables



Air-gauging enables the four lands of Sperry servo valves to be ground without removing the spool from the grinder all four lands to be ground to 0.0002 in. without removing the valve from the machine. A 'shoe' is placed over the spool valve so that it bears on the valve's shoulders opposite to the grinding wheel. In the shoe are drilled four holes, each connected to an air supply and each with a sensitive pressure gauge 'teed' into the pipeline. When the exact amount of metal has been removed from the land, the air flow is de-restricted to give a known pressure drop. The gauges give a steadily decreasing reading as metal is removed and indicate exactly when the job is ground to size.

—ATOMIC POWER—

E.M.I. simulator for Italy

A difficult problem for the designer and operator of nuclear reactors, is to ascertain how the reactor's coolant circuits would behave under conditions, such as the sudden failure of the circulating pumps. These potentially-dangerous conditions cannot, of course, be studied on the reactor itself, but design information can be obtained from a conventional analogue computer used as a simulator. The electronic simulation of variable transport lags is, however, difficult and E.M.I. Electronics have recently supplied to the Centro di Studi Nucleari di Ispra, Milan, a variable time-delay

unit which is said to solve this problem very accurately.

Data can be delayed by a continuously-variable amount determined by the voltage applied to a 'delay control' input, which controls the speed of a loop of magnetic tape passing pre-set positioned record and replay heads. The total range of delay is 0.1 to 10 s, in three ranges, and two separate information channels are provided.

By the use of a precision pulse-width modulation recording system, delay is made continuously variable in conjunction with tape speed, without amplitude distortion.

IN BRIEF

Marconi-India agreement for the manufacture under licence of Marconi designs in India has been signed by the company and the Indian Government.

Comet IV simulator by General Precision Systems has been shipped to South America for Aerolineas Argentinas. G.P.S. have also contracted to supply a flight simulator for the Boeing 707-048 to Aer Lingus.

Hagan Controls are now at 14 Grosvenor Place, London, S.W.1; telephone: Belgravia 6382.

Servo motors, servo components and miniature relays by Siemens Halske are now marketed in the U.K. by B. & R. Relays Ltd.

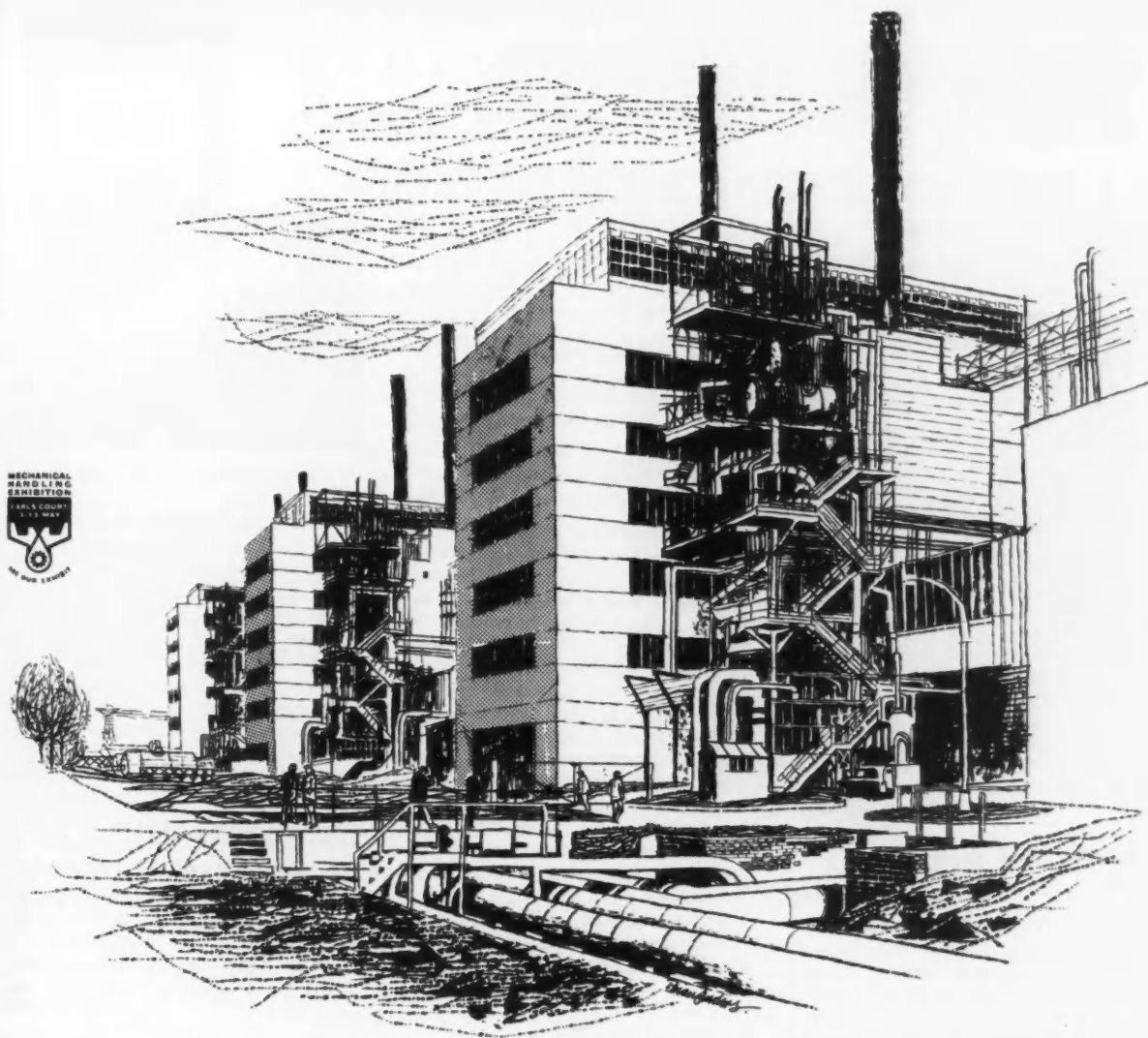
Data-transmission questionnaire is being sent to 350 computer users and potential users by the Post Office.

National Engineering Laboratory is to hold Open Days on June 15 and 16. Applications: The Director, National Engineering Laboratory, East Kilbride, Glasgow.

Ferrites—their Principles, and Application: a course of six lectures will be given at Norwood Technical College by J. Roberts of Imperial College on Tuesday evenings commencing May 10. Details: Norwood Technical College, Knight's Hill, West Norwood, London, S.E.27.

I.F.A.C. Moscow. Applications for representation at the first International Congress on Automatic Control, Moscow, June 27–July 7, should be sent without delay to the Hon. Sec., Group A, B.C.A.C., c/o The Institution of Mechanical Engineers, 1 Birdcage Walk, London, S.W.1. The estimated cost of Conference Fee, travelling and subsistence will be of the order of £200 per delegate.

I.B.M. 709 data processing system with 12 magnetic tape units is to be installed in the C.E.G.B.'s London offices in June 1960.



the applications of Ermeto
high pressure couplings
are practically unlimited

Ermeto high pressure couplings are specified by many leading manufacturers because of their proven reliability under arduous conditions. They are available in mild and stainless steel, brass and aluminium alloy.

Couplings, valves and flexible hose are supplied in a wide range of standard fittings. Non-standard fittings can also be made to meet your specifications.

Technical information and our illustrated catalogue are freely available on request.



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New for Control

A monthly review of system components and instruments

ELECTRONIC TANK-GAUGE

servo-controlled

Shortly to be made in England, under licence from the U.S.A., is a tank gauge claimed to indicate liquid level to within $\frac{1}{8}$ in.

The sensing element in a small cylinder with a $\frac{1}{4}$ in. aerial projecting from the lower end, which maintains a fixed penetration below the surface of $\frac{1}{8}$ in. Very small radio signals are transmitted from a control unit to the aerial, which emits a return signal inversely proportional to penetration depth. Variations of return signal are detected and fed to an electric servo unit which raises or lowers the cylinder to maintain the $\frac{1}{8}$ in. penetration. The servo unit operates a mechanical indicator, with a scale graduated in $\frac{1}{2}$ in. steps.

The Gilbarco gauge, to be made by Firth Cleveland, is corrosion resistant and enclosed in an explosion-proof box. It will operate in tanks of all types at temperatures up to 425°F.

Tick No 523 on reply card

TEMPERATURE INDICATOR

self-balancing

Up to 300 ft of cable between the resistance bulb and indicator may be used with this instrument without affecting calibration or accuracy: 4-way cable is used so that line resistance is added equally to either arm of the bridge.



For remote temperature indication

An oscillator provides a signal voltage at 2 kc/s in order to avoid errors due to 50 c/s-mains pick-up by the signal cable.

For standard models meter span is normally 500°C between -200 and

+500°C; special models are available with suppressed zeros, and covering spans down to 50°C. Scale length is over 13 in., and power consumption for transistor circuitry and servo-motor is 700 mA at 12 V d.c.

Made by Fielden in the Bikini range, who also make power supplies suitable for one or more such instruments.

Tick No 524 on reply card

WAVE ANALYSER

wide frequency-range

The frequency range of this unit is from 5-300 Mc/s, covered in six switched bands. Second harmonics may be measured up to 55 dB down, and higher harmonics up to 70 dB down, provided that the fundamental signal does not exceed the specified input level.

Attenuation is provided in both h.f. and i.f. stages, and the meter is calibrated -2 to +2 dB, so interpolating the 2 dB steps of the i.f. attenuators. Accuracy of scale calibration is given as $\pm 2\%$ on all ranges. Input level limits are 5 μ V to 15 mV r.m.s., or up to 1.5 V r.m.s. when using the two external h.f. attenuators: these figures refer to e.m.f.'s from a 75 Ω open-circuit source.

The model 248, made by Airmec, works from any 50-60 c/s supply at 100-130 V or 200-250 V.

Tick No 525 on reply card

BOILER REGULATOR

for industrial installations

A furnace pressure-regulator for operation in conjunction with a damper motor employs a diaphragm-operated floating change-over contact which may be used for on/off control of one or two motors as required.

It is calibrated in three ranges: 0 to -1.5, +0.75 to -0.75, and 0 to +1.5 in. water gauge, and response rate is variable between 0.75 and 10 seconds. Minimum differential is 0.25 in. w.g. adjustable to a minimum of 0.2 in. w.g.

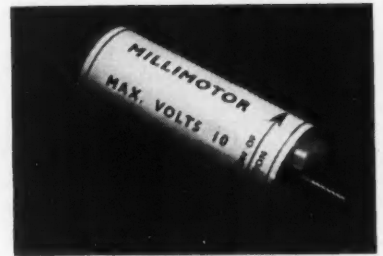
This furnace pressure regulator is by Teddington Industrial Controls.

Tick No 526 on reply card

MINIATURE MOTOR

low current consumption

Designed for use in portable battery-operated equipment, a maximum torque of 15 g cm is available from a motor $2\frac{1}{2}$ in long and $\frac{1}{4}$ in. in diameter. It will operate at voltages from about 3 V to



High torque for small current

9 V (maximum), full-rating current being 155 mA at a speed of 4300 rev/min. Stall current and torque at 9 V are 500 mA and 50 g cm respectively.

The end housings, and shaft sleeve-bearings, are made from nylon, hence require no lubrication. It is claimed by the makers, R. B. Pullin, that the Millimotor has an efficiency of 50%, and will work satisfactorily at temperatures up to 50°C.

Tick No 527 on reply card

TRANSISTORIZED RELAY

sensitive to minute inputs

The 3-stage silicon-transistor amplifier used with this relay operates at a signal current of 15 μ A, and will withstand an overload of one hundred times. It is said to operate at ambient temperatures of up to 65°C.

The overall dimensions of the complete unit are $2 \times 1\frac{1}{2} \times 1\frac{1}{2}$ in., the relay plugging into the amplifier. Contacts and connectors are gold-plated, and the printed circuit fits into a standard polarized 18-way socket.

The amplifier requires a power input of 12 V d.c. at 30 mA. The transistorized relay is available from B. & R. Relays.

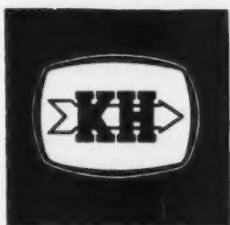
Tick No 528 on reply card

FREQUENCY METER

for impeller-type flowmeters

Designed for use with flowmeters and transducers giving pulsating electrical outputs, this transistorized unit is said to have an overall accuracy better than 0.75%. Principle characteristics are as follows: input signal range, 10 mV to 10 V (r.m.s.) maximum; output, 1 mA into 100 Ω , 100 mV into load greater than 400 Ω ; frequency ranges 10-200, 10-1000 and 10-5000 c/s for full scale deflexion.

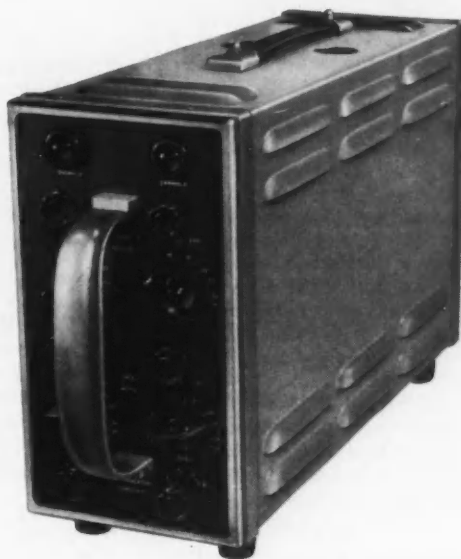
The SE 700 may be operated by a 9 V battery, or from 200-250 V a.c. mains;



ULTRASONIC FLAW DETECTION

**Choose your equipment
from this new comprehensive range**

Kelvin Hughes ultrasonic flaw detection instruments and probes are available for all-manual, semi-automatic and automatic testing techniques. High performance and versatility are obtainable with this comprehensive range of competitively-priced equipment, designed for laboratory work as well as routine inspection schedules. Auxiliary units include Automatic Flaw Alarms, Depth Gauges, Probe Holders and Manipulators.



TWO-CHANNEL FLAW ALARM

This portable auxiliary unit, designed specifically for use with KELVIN HUGHES Flaw Detectors, provides automatic monitoring facilities which hitherto were obtainable only with larger, more expensive equipment. Significant defects are identified automatically and are indicated by warning lights and alarm devices.

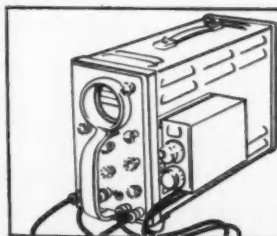
PRINCIPAL ADVANTAGES:

- Removes the onus of signal discrimination from the operator
- Reduces operator fatigue
- Reduces inspection time
- Reduces inspection costs

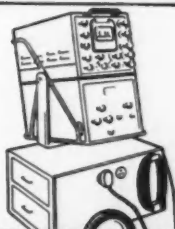
TECHNICAL FACILITIES:

- Simultaneous examination of two independent regions in the material
- Automatic indication of the presence of flaws within these regions
- Independent adjustment of the depth of each region under inspection
- Independent adjustment of the position of each region
- Independent adjustment of the sensitivity within each region

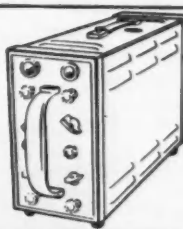
The Flaw Alarm Unit weighs only 20 lb. (9.1 kg.) and the Flaw Detector only 28 lb. (12.7 kg.), thus a completely semi-automatic inspection equipment, which can easily be carried by a single operator, is now available.



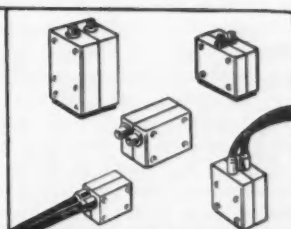
Flaw Detectors, Marks 5F, 5AF. Portable instruments with similar basic specifications. The 5F is a multi-frequency instrument for use with twin or separate type probes, whilst the 5AF, a single frequency instrument, either 1½, 2½ or 5 Mc/s. Also operates with single type probes. (Shown with Depth Gauge attachment).



Flaw Detector Mark 6. Trolley mounted transportable equipment, very powerful and versatile for use with all types of probes and having an exceptionally wide frequency range and high sensitivity.



Two-Channel Flaw Alarm. For use with Mark 5 instruments, a portable auxiliary unit providing semi-automatic monitoring facilities which identify and give warning of significant defects.



Probes. Extensive development by Kelvin Hughes has resulted in a range of standard probes having either single, twin or separate transducers, and a very high performance throughout.

AUXILIARY EQUIPMENT

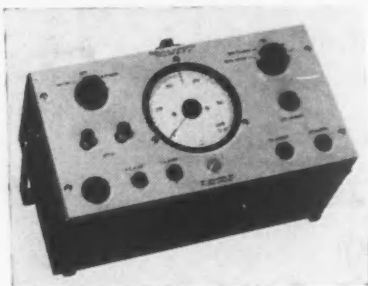
Includes a Depth Gauge for use with all instruments and which will measure thicknesses between 0.1 to 4 ins. with high accuracy. Probe Holders with irrigation facilities for large surface scanning, and remote Probe Manipulators.

KELVIN HUGHES

KELVIN & HUGHES (INDUSTRIAL) LIMITED
Kelvin House, Wembley Park Drive, Wembley, Middlesex
60-72 Kelvin Avenue, Hillington, Glasgow, SW2

KH92A

New for Control



The SE 700 measures frequencies up to 5 kc/s

the power pack is stabilized against mains fluctuation of $\pm 15\%$. Weight is about 9 lb, dimensions are $10\frac{1}{2} \times 5\frac{1}{2} \times 6$ in.

A special model, the SE 710, is available for use where weight and size are dominant factors. This has a frequency range of 10–1000 c/s, with an output of 5 V d.c. for a 1000 c/s input between 10 mV and 10 V (r.m.s.), and an output impedance greater than 10,000 Ω . Weight is 18 oz., dimensions are $2\frac{1}{2} \times 2\frac{1}{2} \times 2\frac{1}{2}$ in., and accuracy claimed is $\pm 0.5\%$. Power supply needed is 22–29 V at 15 mA.

Made by S.E. Laboratories, both models have input impedances of 15,000 Ω and are temperature-compensated over wide ranges.

Tick No 529 on reply card

RECORDING CONTROLLER

potentiometer type

Temperature ranges between wide limits are covered by this recorder to an accuracy given as 0.25% of span. Thermocouples give a variety of ranges from 0–250°C to 0–1200°C (Ni-Cr/Ni-Al), and 0–200°C to 0–600°C (I/C); resistance bulbs give ranges of 0–400°F and -100 to $+100^\circ\text{F}$.

Sensitivity is 0.15% of span, and the chart speed is 1 or 2 in./h: chart life is one month at the lower speed. Ranges are changed by printed-circuit plug-in units, minimum and maximum spans being 5 mV and 100 mV respectively.

Supplied by Ether Ltd., the 'Xactrol' control contacts are rated 230 V, 3 A a.c., control point setting being made from the front panel and indicated on the main scale.

Tick No 530 on reply card

COMPUTER SYSTEM

self-contained unit

A transistorized computer system with a memory of 8008 words is a general-purpose digital computer able to handle both engineering and business applications. The basic system weighs less than 1000 lb.

Standard input-output equipment for the RPC-4000 is a tape typewriter system, complete with typewriter, desk and

punch-read console, all designed as one unit. Made by Royal McBee, it will be available in this country next year, and will cost between £40,000 and £100,000, depending on requirements.

Tick No 531 on reply card

ALTERNATING-CURRENT DETECTOR

for 10 c/s–200 kc/s

A clip-on probe permits the detection of current in a conductor without interrupting the circuit. This has been reduced to the dimensions of a large crocodile clip, and is mounted at the end of a flexible lead to facilitate insertion in otherwise inaccessible locations.

The clip-on probe forms the secondary of a transformer, whose (single-turn) primary is the current carrying-conductor. Negligible impedance is reflected back into the circuit under test, and special feedback arrangements provide a voltage-output proportional to the primary current over the frequency range from 10 c/s to 200 kc/s. The amplified signal from the output terminals may be fed to a valve-voltmeter for current measurement, or to a c.r.o. for waveform monitoring.

The sensitivity control has three settings, and provides an output of 1 V for inputs of 50 mA, 1 A or 20 A. Maximum output is 1 V into 10 k Ω , and accuracy is said to be $\pm 3\%$ above 1 mA.

Made by Dawe, the 618 A.C. is fully transistorized, and may be mains or battery operated; weight is about 6 lb.

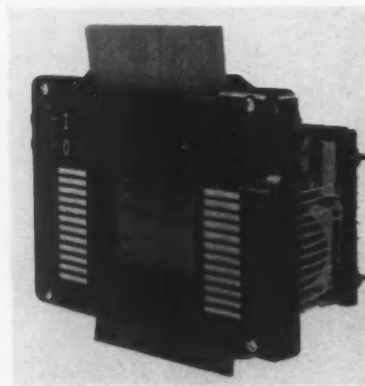
Tick No 532 on reply card

PROGRAMME-CARD CONTROLLER

with 12 separate outputs

By feeding in a pre-cut card, this unit will dictate a complete cycle of events through twelve individual channels: 5-A switches may be fitted.

The minimum time for a complete cycle is 75 seconds, extra long cards being



Twelve-channel control

available for cycles up to twenty days in length. Accuracy to which a programme can be cut is claimed as 1% of total

card timing, and with a fast-moving card the shortest time a contact can remain closed is 200 ms.

The unit may be supplied with a reversible motor, and can provide continuous cycling either by arranging a fast (30 s) run back at the end of a cycle, or by reversing at the end of a cycle and repeating the cycle on other tracks during the reverse.

Made by Engel and Gibbs, who plan a 24-track version in the near future.

Tick No 533 on reply card

MULTIPLE-DISK CLUTCH

electrically operated

A new multiple-disk oil-type electric clutch is available for the first time in Britain. These clutches have been developed to answer the demand of machine tool builders for an electrically actuated



Designed for rapid cycling

clutch for oil operation, that has high torque-capacity, with compact size, and stands up to rapid cycle operation.

The range available covers seven standard clutch sizes ranging from one with a friction surface diameter of 3 in. and a torque rating 1 h.p. per 100 rev/min., to one with a friction surface diameter of 8 in. and a torque of 15 h.p. per 100 rev/min.

Power for excitation ranges from 16 to 24 watts depending upon size, and fields are available for either 6 or 90 volt operation. Made by Westool.

Tick No 534 on reply card

MINIATURE AIR VALVES

solenoid-operated

A range of miniature solenoid-operated air-valves, employing balanced-spool—floating-sleeve valving action, is suitable for the operation of small air cylinders. Where high piston speeds are not required they will operate cylinders up to 4 in. bore.

Operating speeds of 450 and 600 operations per minute are quoted for continuous and intermittent working respectively. Vacuum or air pressures may be used up to 300 lb/in². The solenoids are rated for continuous operation and may be held energized if necessary:

PNEUTECHNIQUE

*air-operated proportional control gives
instant, flexible, reliable control of processes*

Negretti & Zambra air-operated proportional controllers are eminently suitable for all applications requiring a simple but efficient form of control.

Negretti & Zambra have made an extensive study of the many problems involved in the application of automatic control to industrial processes; their range of controllers is one of the widest available and has been designed after many years of close co-operation with the industries concerned.

● WIDE VARIETY OF CONDITIONS

These instruments control temperature, pressure or vacuum, humidity, liquid level, specific gravity of liquids and many other conditions.

We illustrate a single-pen recording controller of the proportional type.



NEGRETTI

THE NAME THAT MEANS PRECISION ALL OVER THE WORLD

Agents or subsidiaries in all major countries.

● ADVANTAGES OF COMPRESSED AIR OPERATION

Compressed air is easily and cheaply produced, easily cleaned, dried and disposed of by venting; it is non-corrosive and causes no wear on the component parts of the controller. Performance is virtually unaffected by variations in temperature. Above all, compressed air offers *great flexibility of action*.

● ROBUST CONSTRUCTION

These controllers are designed to withstand adverse operational conditions. The practical design, construction and first-class workmanship make possible *a full guarantee for two years*.

● SIMPLICITY OF PRINCIPLE

This and simplicity of design result in a sustained accurate performance; adjustment and maintenance are remarkably easy.

● HIGH SENSITIVITY AND RAPID ACTION

Only a very small change in the controlled condition is required to actuate the instrument and so restore the required conditions.

● HIGH-EFFICIENCY MEASURING UNITS

The mercury-in-steel system fitted to temperature controllers is unaffected by vibration and varying barometric pressure.

The elements fitted to pressure controllers are sensitive but extremely reliable — diaphragm types have been designed to minimise friction, backlash and hysteresis; Bourdon tubes have been developed to provide a very high degree of accuracy during years of service.

We will be pleased to send you a copy of our fully illustrated booklet No. R30/IP on your request.

& ZAMBRA

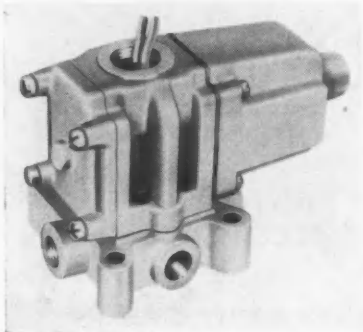
Factories at Barnsbury, London N.1; Aylesbury, Bucks; Chobham, Surrey.

Head Office: 122 Regent Street, London W.1.

Telephone: REGent 3406.



New for Control



Fast operation, low power-consumption

for 230 V a.c. supply, holding current is about 0.125 A, and surge current during actuation is below 0.5 A.

Valves are tapped for $\frac{1}{4}$ in. pipe, and spool and sleeve are made of stainless steel: body is corrosion resistant aluminium.

Made by T.A.L. Numatics, the 1 SGA 4 has dual exhaust ports to permit throttling of exhaust for speed-control in either direction of piston movement.

Tick No 535 on reply card

D.C. AMPLIFIER

as in Simlac computer

The high-gain printed-circuit amplifier incorporated in the Simlac computer is now available as a single unit. It consists of a three-stage main amplifier section having a d.c. gain greater than 10^5 .

The noise level on input is less than 200 μ V, and the drift figure quoted is 10 μ V. At unity gain, achieved with the associated computing resistances, the amplifier response is 3 dB down at 16 kc/s. The zero-set control is mounted on the front panel of the amplifier, and to balance the unit it is used with the neon overload indicator.

Principal characteristics are as follows: open loop d.c. gain, 10^5 ; phase shift up to 100 c/s at unity gain, 0.05; drift over 24 hours at unity gain, better than 10 μ V; output at 10 mA, ± 100 V; noise in input on bench, 100 μ V. Further information obtainable from the makers, Short Bros. & Harland.

Tick No 536 on reply card

VOLTAGE SUPPLY

to provide stable reference

A solid-state d.c. reference source, designed for use with electronic self-balancing recorders, indicators and controllers, provides a stable, ripple-free output of 5.0 mA at 5 V for the slidewire of the instrument measuring circuit.

Two zener-diode stages in cascade reduce the effects of normal supply variations by a factor of over 200, while individual temperature compensation of these stages ensures that the output is

substantially independent of changes in ambient temperature between 10 and 70°C. An inherent advantage claimed is that the unit will operate with only slightly reduced accuracy if the supply voltage is reduced to as little as 30% of its nominal value. Supply may be 200–250 V by six-position selector: consumption is approximately 3 VA.

The d.c. output is isolated from earth, and a screened and balanced mains transformer effectively isolates it from the mains supply. This feature is of value in certain measuring circuits having a finite impedance to earth.

Made by George Kent, the accuracy is given as 0.05% at 40°C ambient and normal supply voltage.

Tick No 537 on reply card

TRANSISTORIZED COUNTER

with six-figure display

The frequency standard of this electronic counter is an oven-controlled 1-Mc/s crystal oscillator, claimed to have an accuracy when mains-operated of ± 1 part in 10^6 at 25°C, and ± 5 parts in 10^6 over the range 0 to 40°C.

Facilities are provided for the direct measurement of frequency up to 1 Mc/s, for measurement in a range of time units of the duration of 1 or 10 periods of the incoming wave-form, for the counting of regular or random electrical pulses, and for the measurement of time from 1 microsecond to 2777 hours (10^7 seconds). Timing pulses, from 0.1 to 10^6 p.p.s. in decade steps, are available as



Output for external recorder

an output from the counter. The frequency measuring period is 0.1, 1.0 or 10 seconds, and the display time is from 1 to 5 seconds or hold, with manual or automatic repetition of count. Self-checking facilities are incorporated for testing both counter chains, and provision is made for the connexion of an external recorder.

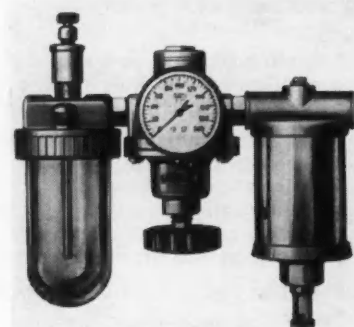
The input impedance is 100 k Ω , with a sensitivity of 300 mV r.m.s. Maximum input signal is 250 V a.c. or 500 V d.c. The TCI measures $12 \times 9 \times 6$ in., and is made by Advance Components.

Tick No 538 on reply card

LUBRICATION CONTROL

for air-powered machines

Three units comprise a system for providing clean air and lubrication to air powered tools, drills etc. They are, in order, a moisture separator, to remove water vapour and impurities frequently present in compressed-air lines; a pressure-reducing valve, which automatically



Automatic pressure control

adjusts pressure to the pre-set figure on the gauge; a lubricator which provides lubrication by means of an airborne oil fog.

Made by B.E.N. Patents, the Controlube unit is available for $\frac{1}{4}$ and $\frac{1}{2}$ in. B.S.P.

Tick No 539 on reply card

MILLIVOLTMETER

automatic polarity sensing

Features of a d.c. millivoltmeter are high input-impedance and a wide variety of ranges. Voltages are covered in two spans: 100 μ V–10 V f.s.d. in 11 ranges, with input impedance 1 M Ω , and 10 mV to 1000 V f.s.d., also in eleven ranges, with input impedance of 100 M Ω . Twenty-two current ranges cover 100 μ A to 10 μ A f.s.d. The meter is automatically switched to the polarity of the voltage or current to be measured, which is indicated by two luminous columns.

Scale length is 5 in., and an internal standard source simplifies calibration. Accuracy is given as 5% f.s.d. in the 0–100 μ V range; 3% f.s.d. in other ranges. The Philips GM 6020 will operate on any normal mains supply at 40–100 c/s; distribution by Research and Control Instruments.

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QUICK LOOKS

A series of high-altitude silicon cartridge rectifiers covers the p.i.v. range from 600 to 10,000 V. They are ceramic-encased to prevent surface creepage and minimize flashover problems encountered in high-altitude operation. Units tested to

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New for Control

90,000 ft simulated-altitude operated at 16,000 V with no evidence of corona.

Designated JEDEC types 1N2373 through 1N2381, this hermetically sealed cartridge series provides d.c. output currents from 75 to 250 mA (at 25°C) and is manufactured by International Rectifier Company.

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The probe unit of this meter is polythene shielded, and has a detachable bottom cup which will hold sufficient solution (5 ml) to give a reading. Length of lead



Portable pH meter

between probe and meter is normally about 3 ft, but may be extended to any reasonable length.

The model 700 is temperature compensated, and accuracy is claimed to be within 0.2 pH. Made by Analytical Measurements, it has a scale-length of 7.2 in. and weighs approximately 5 lb.

Tick No 542 on reply card

Vibration measurement in the field may be made with a transistorized meter having a frequency range of 10 to 1000 c/s. The pick-up has a maximum peak to peak amplitude of 0.6 in., and a maximum peak acceleration of 10,000 in./s². The Dawe type 1431 weighs about 7½ lb with batteries.

Tick No 543 on reply card

The output of a d.c. supply is 0-250 V at 50 mA, plus an a.c. output of 6.3 V at 1.5 A. Claude Lyon's PV-250-B has switched metering covering four ranges, 0-10, 0-50, and 0-300 V, and current in the range 0-50 mA.

Tick No 544 on reply card

Miniature switches weighing less than 1/28 oz are claimed to be the lightest on the market. Made by Texas Instruments (U.S.A.), the Klixon AT1/1 is hermetically sealed, and is rated at 3 A, 28 V d.c. Ambient temperature range is -65 to +275°F.

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Capacitances from 1111 µF down to 0.002 µF can be measured with 0.2% accuracy by means of a three-terminal transformer ratio-arm bridge. Its discrimination and stability make it suitable for such applications as the measurement of the temperature coefficient of capa-

citors, or changes in valve interelectrode capacitance. Made by Marconi Instruments, the TF 1342 has its own 1000 c/s oscillator, and will measure effective shunt resistance between 1 and 1000 MΩ.

Tick No 546 on reply card

A new range of direct-writing, ultra-violet galvanometer recorders has models with chart widths up to 6 in. (25 available input channels) and up to 12 in. (fifty available input channels); chart speeds are variable in twenty steps from 0.05 to 80 in/s. Galvanometers are available to cover frequency ranges from 0-100 to 0-5000 c/s. Further information from S.E. Laboratories.

Tick No 547 on reply card

Plug-in miniature sealed relays will switch 2 A (resistive load) at 28 V d.c. or 110 V a.c. Manufactured by Magnetic devices, who claim good performance under vibration in any plane between 30 and 2000 c/s. Close and release times are 3 ms and 2 ms respectively.

Tick No 548 on reply card

A size 23 sweep-resolver for radar sweep-circuits has a flat frequency response extending into the 100 kc/s range, peaking at 500 kc/s.

Made by Plessey, the 113D8H has a voltage range of 0-30 V and an operating temperature range of -55 to +75°C.

Tick No 549 on reply card

Miniature relays weighing less than 1 oz. are made in two basic forms, having either 2 or 4 change-over contacts. Coils are available for voltages up to 60 V d.c. The contact rating is 1 A non-inductive; release time, 2-4 ms.

Made in Germany, distribution in England is by Londex.

Tick No 550 on reply card

Micro-switches measuring 0.5 × 0.35 × 0.2 in. and weighing 1/28 oz are now made by Honeywell. The ISX1-T is rated 24 A surge, 7 A resistive and 4 A inductive, for operation at 28 V d.c. or up to 230 V a.c. A minimum life of 25,000 operations is claimed.

Tick No 551 on reply card

Voltage converters are available in a complete range with ratings of 2-120 W. Supply voltages from 6 to 28 V d.c. are catered for, with outputs from 90 to 300 V d.c. The makers, Aveley Electric, state efficiency as 76% overall.

Tick No 552 on reply card

Now in production is the SCR 96 series of silicon-controlled rectifiers. Maximum average forward current is 10 A, and maximum peak-inverse voltages range from 25 V for SCR 961, to 200 V for SCR 965. Made by G.E.C., typical gate current to fire is 20 mA at +1.5 V.

Tick No 553 on reply card

Hermetically sealed plugs with 5, 7 or 9 contacts are designed to be suitable for soldering into ½ in. diameter holes. The BHM series is rated at 5 A, 1500 V for

operation at sea-level, or 5 A, 450 V, at 60,000 ft. Made by Electro Methods, all metal parts are gold-over-silver plated.

Tick No 554 on reply card

INDUSTRIAL PUBLICATIONS

Variable speed drives are described in a 7-page pamphlet from Lancashire Dynamo Nevelin.

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Sealed gas-blowers are shown in a leaflet from Davidson and Co.

Tick No 556 on reply card

Precision ball bearings are featured in a new catalogue from E.M.O.

Tick No 557 on reply card

The Teletronic Variostat is explained in a data sheet from Drayton Controls.

Tick No 558 on reply card

Semiconductors. Abridged technical data is given in a booklet produced by Ediswan.

Tick No 559 on reply card

Overhead handling equipment is described in a bulletin published by British Monorail.

Tick No 560 on reply card

Contra-rotating axial-flow fans for marine and industrial applications are shown in a publication from Davidson & Co.

Tick No 561 on reply card

Potentiometers are the subject of 13 data sheets from Penny & Giles.

Tick No 562 on reply card

Automatic boiler control for unit system power plant is the subject of a new coloured catalogue produced by Electroflo.

Tick No 563 on reply card

The transient storage oscilloscope by Cawkell is described in an 8 page pamphlet.

Tick No 564 on reply card

E.E.A. Annual Review of 1959 gives a short summary of the achievements of the Electronics Industry.

Tick No 565 on reply card

Thermostats, and oil-burner controls are two of the many components featured in a new illustrated catalogue from the Rheostatic Co.

Tick No 566 on reply card

Radio and electronic components are described in the February issue of A.E.I.'s Quarterly Review.

Tick No 567 on reply card

Tally counters are illustrated in a catalogue issued by Trumeter.

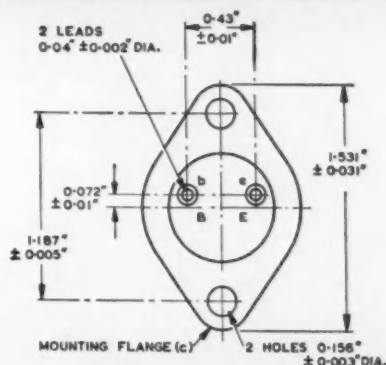
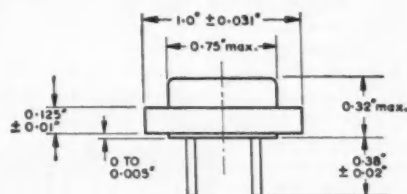
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'Electronics Post.' First issue of a quarterly export journal to be issued by E.M.I.

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'News & Review' is the title of a bi-annual publication from Gallenkamp dealing with components, patents etc.

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Maximum Ratings (Absolute Values)

	XC155	XC156
Peak collector to base voltage (volts).....	-80	-100
Peak collector to emitter voltage, base open circuit (volts).....	-50	-65
Peak collector to emitter voltage, base and emitter joined or with an external base/emitter circuit resistance less than 40 ohms (volts).....	-65	-80
Peak emitter to base voltage (volts).....	-60	-60
Peak collector current (amps).....	-10	-10
D.C. Collector current (amps)	-5	-5
Collector dissipation (mounting flange temperature 85°C) (watts)....	10	10

Switching Characteristics (Common Emitter) (Typical production spreads)

D.C. Current gain ($V_{ce} = -1.5V$, $I_c = -4A$)	minimum	20	20
	average	26	26
	maximum	50	50
D.C. Collector to emitter saturation voltage ($I_c = -4A$, d.c. $I_b = -400$ mA) (volts)	average	-0.4	-0.4
	maximum	-0.8	-0.8

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Book Reviews

Integration

Process Integration and Instrumentation. *Electrical Development Association.* 1959. 200 pp. 8s. 6d.

The control engineer will find this book a rather elementary account of the uses of automatic control in industry with detailed descriptions of much of the equipment and instrumentation involved. It is more a book for the business executive, who, perhaps lacking a technological education, nevertheless wants to know what all this control business is about. The book should satisfy his needs in that it gives a background to the problem of control and automation. It seeks to arouse the reader's interest by discussing the problems of modern manufacture and how automatic methods of control can lead to an improvement in the quality and quantity of production while reducing the labour and material content.

Naturally, as the book has been prepared and published by the Electrical Development Association, the emphasis is on electrical methods, but bearing in mind the readership aimed at, this is not necessarily a disadvantage.

There are chapters on Modern Manufacturing, Automatic Control, Sensing, Instruments and Instrumentation, Electrical and Electronic Links, Actuators and Servomotors, followed by a series of chapters on Industrial Applications, Use of Computers, Machine Control, Quality Control and Progress towards Automation. The chapter on Industrial Applications gives a very representative set of examples and will be helpful to many who wish to appreciate the wide uses to which automatic controls are now being put. For production managers and others who have to make decisions regarding improving production methods, this chapter is probably the most valuable in indicating possibilities and arousing interest.

The main criticism of the book is that it says little about the savings affected by the introduction of automatic control. Some discussion of these matters would have been worth while.

The book is well printed and illustrated, and can be recommended to business executives, production managers and others who want an introduction to the possibilities of automatic control.

DENIS TAYLOR

Science

Science in Industry—Policy for Progress by C. F. Carter and B. R. Williams. *Oxford University Press.* 1959. 186 pp. £1 1s.

This book is the third of a series of reports written for the Science and Industry Committee.* It contains suggestions for policy and action, by industry and by the Government, which could assist the more effective application of science to British industry.

Perhaps the most valuable aspect of this excellent publication is as a guide to general management in British industry as to the factors on which to base judgment and action with regard to scientific policy. Although the application of science in Britain has increased tenfold as between 1928 and 1958, it is expected that research and development expenditure will continue increasing, particularly in the older-established industries which should be progressively finding the scientific basis of their inherited crafts.

Much attention is given to the economical aspect of research, and small firms are recommended to make the maximum use of their ears and eyes to bring in the fruits of external research and development, rather than to overstrain their own financial resources. Indeed, the problems of co-

* Sponsored by the British Association for the Advancement of Science, the Royal Society of Arts, and the Nuffield Foundation.

ordination and cross-fertilization of ideas, and the problem of communications in general, are very thoroughly dealt with, and a useful practical suggestion for small firms is to spend a reasonable amount of time in studying which scientific literature to peruse in order to keep in contact with new ideas. It is important, after this list has been selected, to extract effectively from it, and to secure wide circulation in the organization. Special attention should be given to the problem of the status of research managers, to ensure that the significance of scientific developments is thoroughly understood by the board of directors. In this connexion special warning is issued to family firms, where the scientific side of the business may be neglected if the board of directors is exclusively recruited from the family circle.

Whilst the book emphasizes the need for more initiative to come from industry itself, and for industry to sort out its own problems, it nevertheless considers that further assistance is required from Government initiative, particularly in backward industries. With reference to existing research associations, more effort is proposed for advisory or educational services to assist directly individual firms without adequate research resources of their own. It is also proposed that the research associations should set up development companies capable of placing contracts for the development of their inventions to ensure their effective actualization in industry. It is even suggested that occasionally it may be necessary to create State development companies to manage developments in a defined field.

Particularly recommended appears to be the extension of private research companies that will undertake research and development on a business basis, and that can bring new techniques to bear on old subjects. In this context it is also considered that wider use could be made of part-time arrangements with independent specialized consultants, a suggestion which I consider to be not without merit.

In general, this first-class book can be recommended to all interested in the problem of the organization of science for industrial purposes, but perhaps it can be particularly recommended to members of top management who may feel vaguely uneasy about what is happening in research in their own organizations.

D. B. FOSTER

Productivity

People and Productivity by A. B. Waring. *British Productivity Council.* 1959. 95 pp. £1 5s.

For those seeking ways of improving industrial relationships this book should provide a practical working guide to the implementation of schemes that are so often only sketchily referred to in pseudo-scientific terms. The author's attention to detail, and the many illustrations included, clearly show the thought that has been applied to establishing stimulating working conditions in at least one factory group. It is unfortunate that it would be difficult to promulgate a good many of the proposals in the smaller organization. The general layout and clarity of the book leave little to be desired, but had it been published in a more conventional size it would have been easier to find room for it on the bookshelf, where easy access would make it an ideal reference book to have within reach.

JOHN ISAACS

Literature Received

Basic Electronics by Van Valkenburgh, Nooger & Neville Inc. *Technical Press Ltd., London. The Brolet Press, New York.* 1959. 625 pp. £2 14s ★ 701

Basic Electricity by Van Valkenburgh, Nooger & Neville Inc. *Technical Press Ltd., London. The Brolet Press, New York.* 1959. 588 pp. £2 5s ★ 702

Use of Moiré-fringe Techniques for the Measurement of Velocity by G. Hodgson. *National Engineering Lab.* 1959. 14 pp. ★ 703

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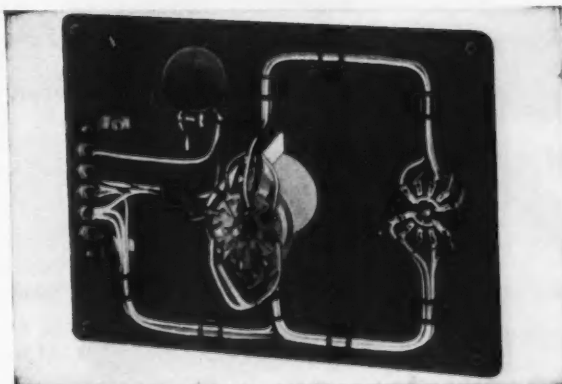
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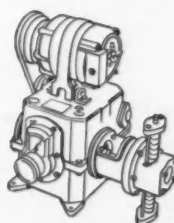
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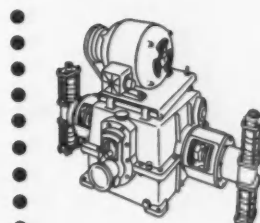
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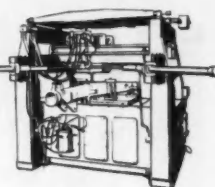
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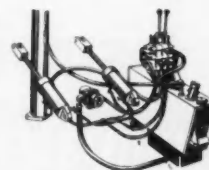
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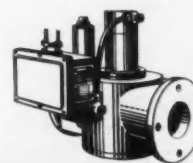
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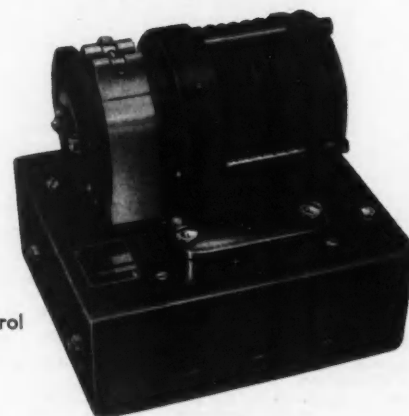
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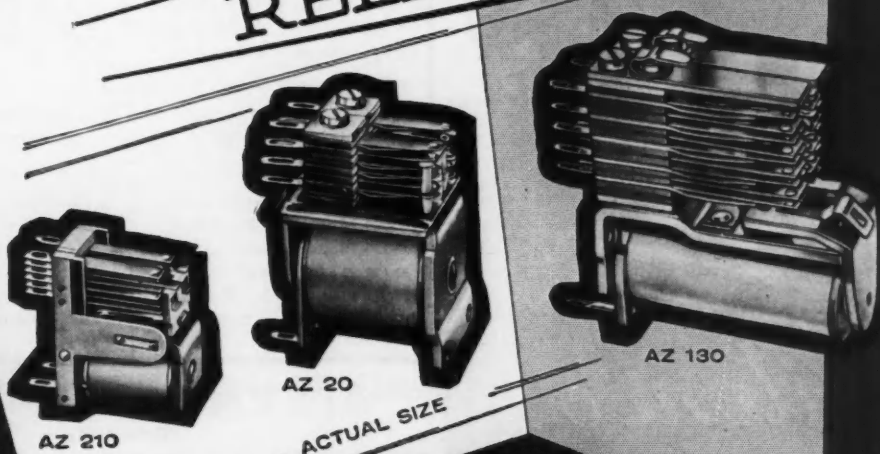
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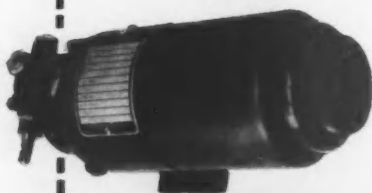
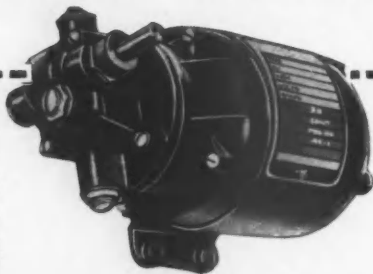
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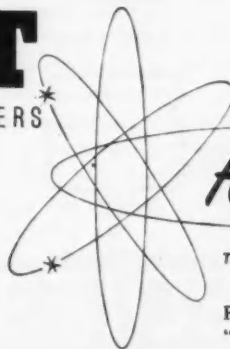
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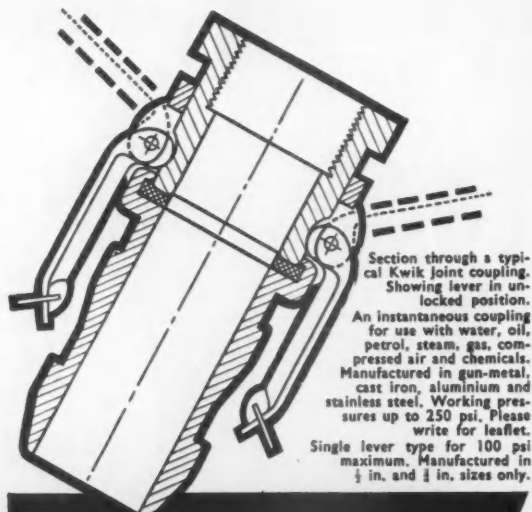
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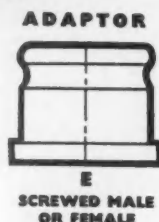
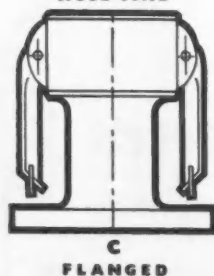
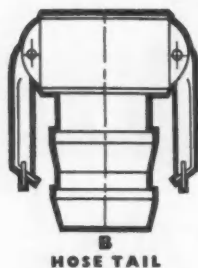
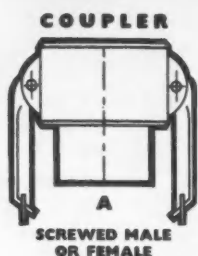
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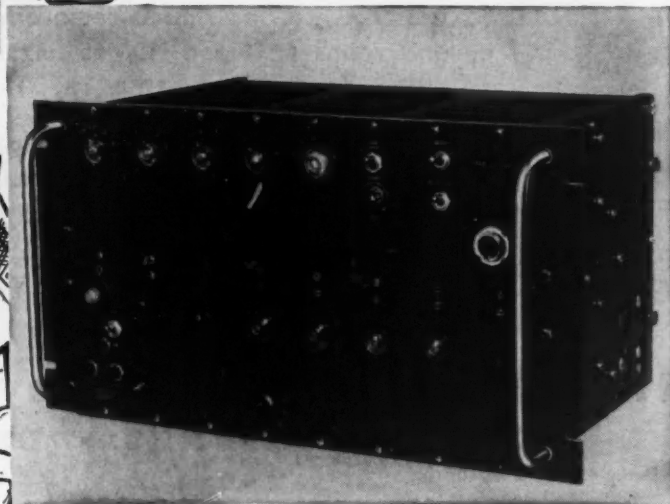
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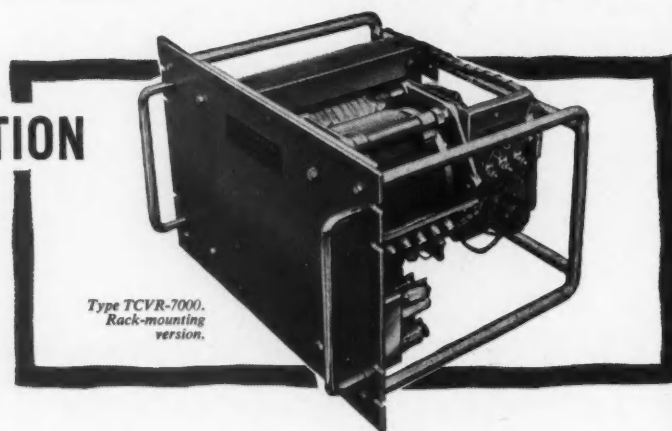
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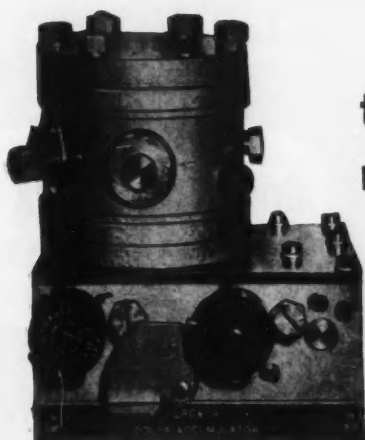
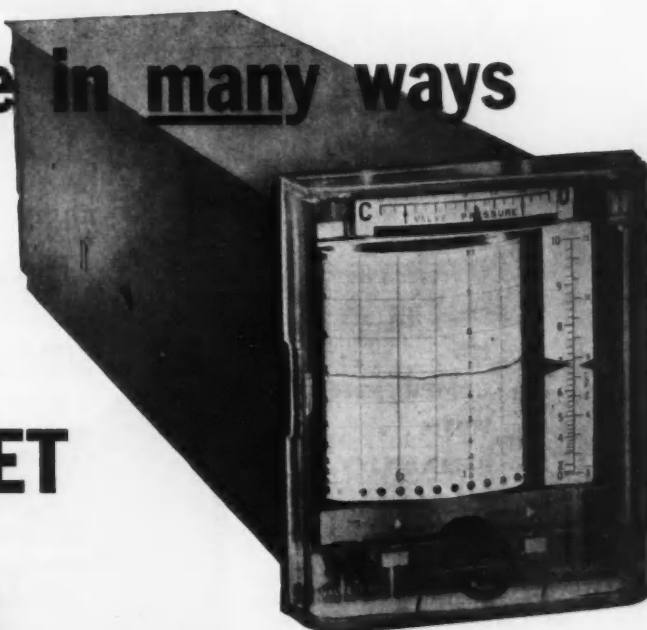
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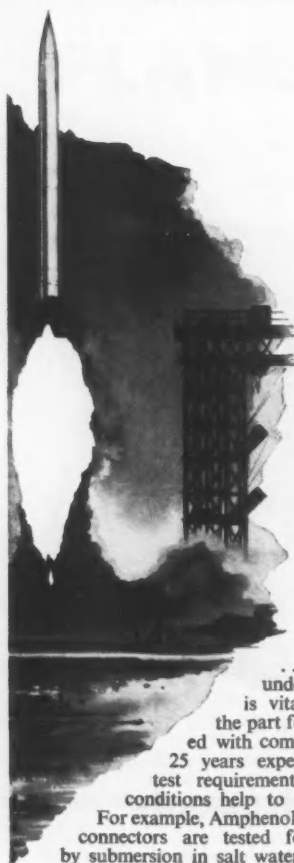
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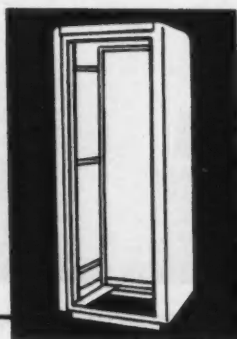
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3 UNIT	19"	5 $\frac{1}{4}$ "	8s. 0d.	11s. 6d.	5s. 6d.	10s. 3d.
4 UNIT	19"	7"	9s. 7d.	13s. 6d.	6s. 9d.	12s. 10d.
5 UNIT	19"	8 $\frac{3}{4}$ "	10s. 8d.	14s. 6d.	7s. 8d.	13s. 6d.
6 UNIT	19"	10 $\frac{1}{2}$ "	13s. 6d.	18s. 6d.	7s. 11d.	14s. 9d.
7 UNIT	19"	12 $\frac{1}{4}$ "	16s. 3d.	£1 2s. 3d.	9s. 8d.	17s. 3d.
8 UNIT	19"	14"	17s. 0d.	£1 3s. 0d.	10s. 10d.	19s. 7d.
9 UNIT	19"	15 $\frac{3}{4}$ "	£1 0s. 0d.	£1 7s. 6d.	11s. 3d.	£1 0s. 7d.
10 UNIT	19"	17 $\frac{1}{2}$ "	£1 4s. 6d.	£1 14s. 6d.	12s. 0d.	£1 3s. 4d.
11 UNIT	19"	19 $\frac{1}{4}$ "	£1 8s. 0d.	£2 0s. 0d.	12s. 5d.	£1 6s. 4d.
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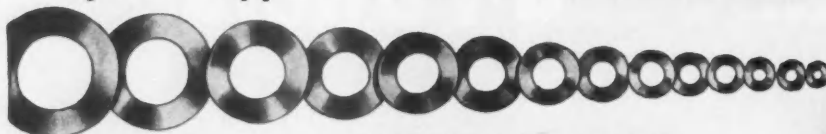
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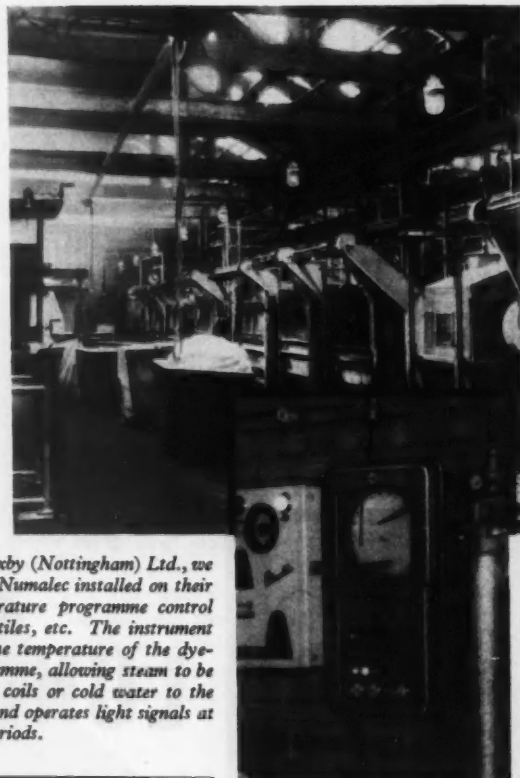
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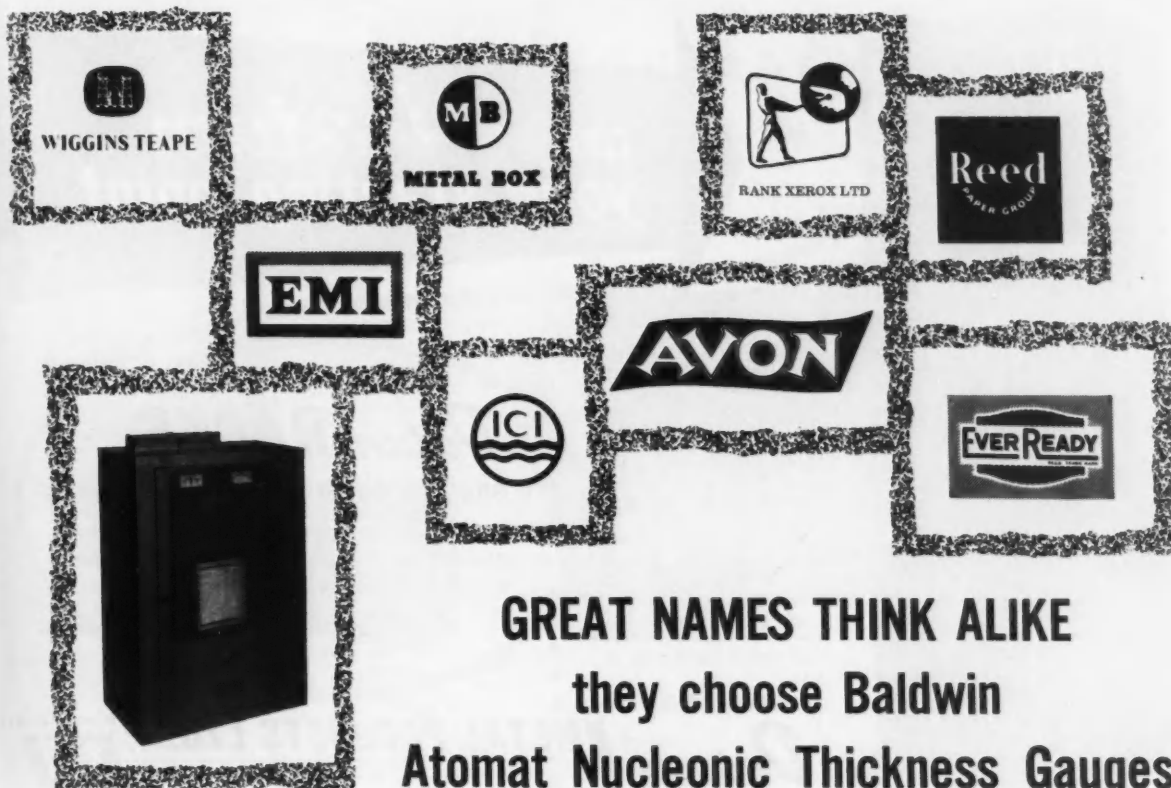
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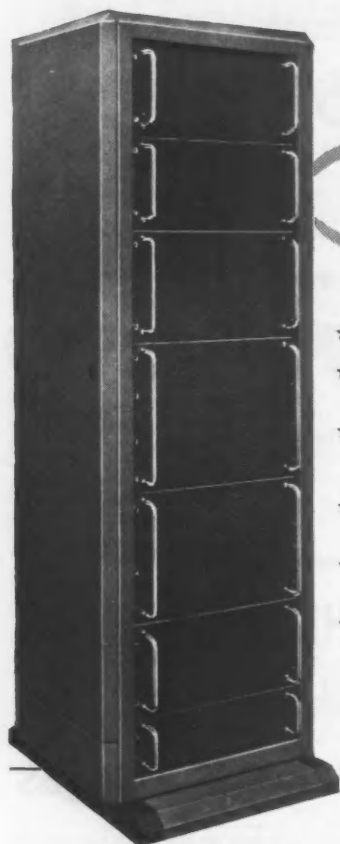
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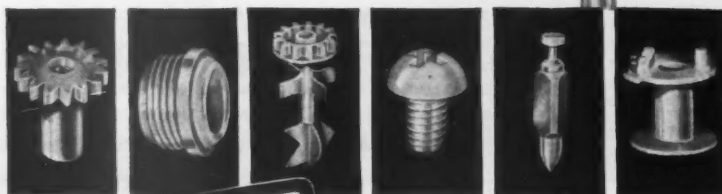
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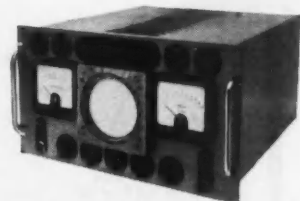
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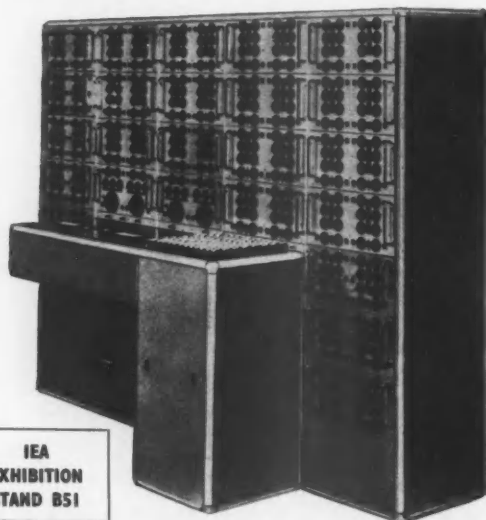
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SWITCH:

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**MANUFACTURING ELECTRICAL ENGINEERS • CONTROL AND
LABORATORY APPARATUS**

On Admiralty, Principal Ministries and Post Office Lists,
A.I.D. and A.R.B. approved.

RELIANCE *put the "POINT 5"*

for COMMERCIAL CIRCUITS

for PRINTED CIRCUITS

for
TRANSISTORISED
EQUIPMENT

for
ELECTRONIC
COMPUTERS



WHENEVER IT'S A MATTER OF SPACE....

Whenever it's a matter of space this new *wire-wound* potentiometer, of only 0.5 in diameter and weighing only 7 grammes, will eliminate your difficulty.

FIVE STAR FEATURES

- ★ ONLY 0.5 in diameter, 0.5 wattage rating and ONLY 7 grammes in weight.
- ★ A wide resistance range of 10 ohms — 10,000 ohms.
- ★ Resistance accuracy of $\pm 5\%$ as standard.
- ★ High end stop torque.
- ★ Facilities for increasing operating torque.

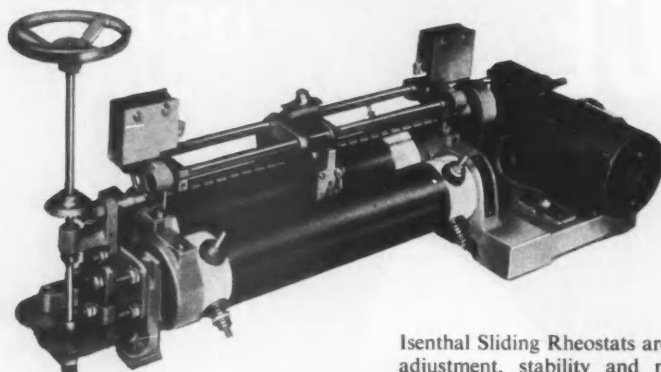
Full electrical and mechanical details are given in Data Sheet No. 10 available on request.

Available in two versions, one for standard wiring circuitry, the other for printed circuit application with locating centres 0.2 in apart, both versions are ideal for transistorized equipment etc.

RELIANCE MANUFACTURING COMPANY (SOUTHWARK) LIMITED
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ISENTHAL RHEOSTATS *for reliable control*



Isenthal Sliding Rheostats are unsurpassed for their smoothness of adjustment, stability and mechanical strength. They are all electrically self cleaning and conservatively rated and the tube terminal stems are firmly locked in their mountings. Straight and graded windings in a wide range of ohmic values and current carrying capacities are obtainable and special characteristic windings can be supplied.

The motor driven rheostat illustrated here is just one of the wide range manufactured by Isenthal.

Please write for illustrated leaflet 255R.

ISENTHAL

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LEARN ABOUT THIS NEW CONCEPTION OF SMOOTH RUNNING . . .

- Even load distribution. Maximum permissible speed $\frac{300,000 \text{ r.p.m.}}{\text{shaft dia. mm.}}$
- All needles supplied to a tolerance of $\pm 0.00004''$ on diameter.



CAGE GUIDED NEEDLE BEARINGS

Head Office and Factory
INA NEEDLE BEARINGS LTD.
Dept. C. Dafen, Llanelli. Tel: Llanelli 2056
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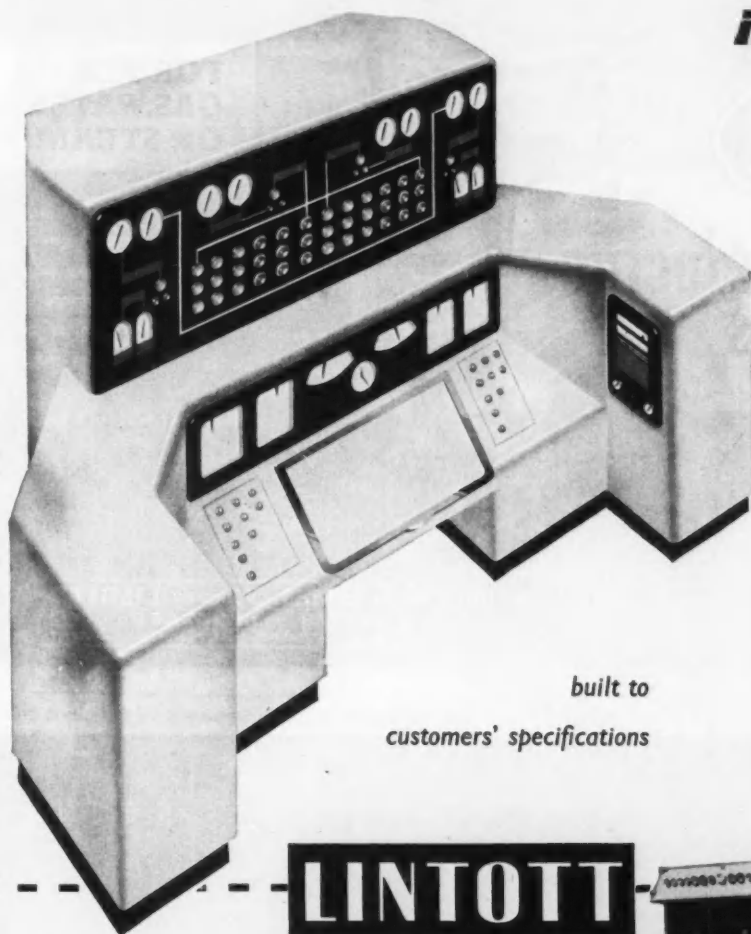
Ina Bearings are manufactured in Great Britain, France and Western Germany.

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of the
Technical
Handbook
and New
Catalogue



* **the case for perfect housing**

in electronics



*built to
customers' specifications*

FOR CONTROL

Desks and Panels

Lintott fabrication serves the electronic and nucleonic industries with Control Desks and Panels that enhance the operating scheme. Working in close collaboration with designers, Lintott produce units for all forms of process control, burner control, nuclear control, etc. This includes sheet metal work, surface finishing, flow diagram mounting and installation of instruments and switchgear. Perfect housing helps to sell your equipment. Let Lintott quote for construction on your next project.

LINTOTT

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a flexible system of cabinets

Lin-cabinets provide a standard and yet completely flexible system for housing electronic and electro-mechanical equipment. They are designed to accommodate any arrangement of components and any combination of chassis. Each unit is self-contained, with built-in cooling or heating facilities, and are suitable for slight pressurisation. The three standard drawers of 8", 12" and 16" can be used in any combination to give a total height of 52" and any number of cabinets can be interlinked. Lin-cabinets are K114 approved for the three Services and lend themselves to many applications. Plan your equipment layout with Lin-cabinets in mind and enjoy low installation costs, low maintenance costs, with maximum efficiency.

Data Sheet LC. No. 1.




H. & E. LINTOTT LTD., Horsham, Sussex.

Telephone: Horsham 3316 Telex 8746

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CERTAIN SIZES IN
STAINLESS STEEL FOR
CORROSIVE MEDIA



**FOR AIR,
GAS, WATER
OR STEAM**

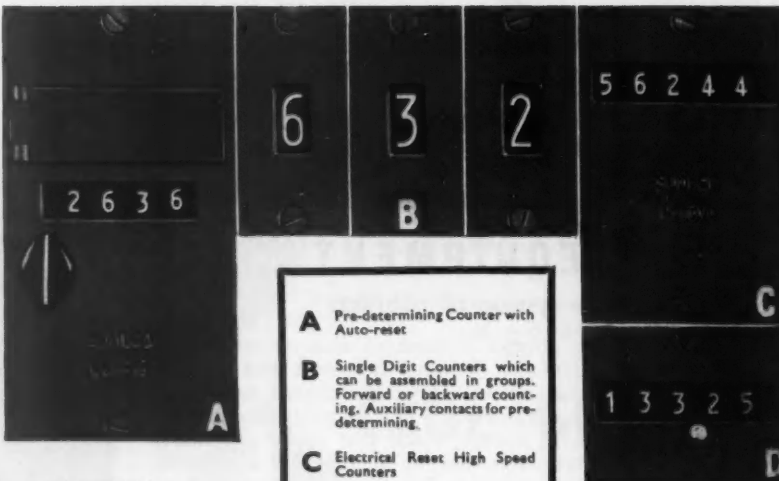
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VALVES**

These valves are designed to give a minimum sympathetic pressure drop with variations of upstream pressure, a maximum flow with a minimum working drop, and absence of pressure creep with no flow.

Sizes available are from $\frac{1}{4}$ to 2 B.S.P. or A.P.I.

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TELEPHONE GLOUCESTER (400.2.3) TELEGRAMS & CABLES COMPRESSOR GLOUCESTER

**small
impulse
counters**



A Pre-determining Counter with Auto-reset

B Single Digit Counters which can be assembled in groups. Forward or backward counting. Auxiliary contacts for pre-determining.

C Electrical Reset High Speed Counters

D Instantaneous Manual Reset High Speed Counters (10 or 25 impulses per second)

Our range of counters offers in the most compact form types for all requirements. The total full size width of the group above is only 6 inches.

Send for full details of the above and other counters in our range to

STONEBRIDGE
CONTROLS & INSTRUMENTS

**THE STONEBRIDGE
ELECTRICAL CO. LTD.**
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Telephone: TRAfalgar 1444

Agents and Licensees in U.K. for "SODECO", GENEVA.

Here is a 12v. stabilized d.c. supply at 4 amps!



How to obtain high current constant voltage D.C. supplies?

You could use cumbersome batteries with their need for constant attention, but it is far simpler and certainly more reliable to use one of the new 'Advance' Constant Voltage D.C. Supply Units. This latest development in the application of Constant Voltage Transformers can be used to provide various d.c. supplies up to quite high current levels, as used in computers and data processing equipment. We shall be pleased to arrange for one of our technical representatives to call and discuss your requirements.

These new D.C. Supply Units . . .

- Provide HIGH CURRENT OUTPUT AT LOW COST
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- Operate with HIGH EFFICIENCY

TYPE	OUTPUT RATINGS		NETT PRICE IN U.K.
DC.1	6 volts	1.25 amp	£20
DC.2	6 volts	4.00 amps	£25
DC.3	12 volts	1.25 amp	£20
DC.4	12 volts	4.00 amps	£27
DC.5	24 volts	1.00 amp	£20
DC.6	24 volts	5.00 amps	£30
DC.7	48 volts	1.00 amp	£20
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Advance

CONSTANT VOLTAGE

D.C. POWER SUPPLIES

Full technical details available in leaflet G 59



Advance

COMPONENTS LIMITED

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GD 77

CONTROL April 1960

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RELAYS?

Everything points to DEPENDABLE

Our wide range of relays have one thing in common—they are manufactured to the highest standards. Whether your need is for Automation, Transistor, Type 3000 or Type 600 Relays, you can leave your specifications in our hands with confidence.

Prototypes can be delivered in 1/7 days, and quotations for quantities and special orders given on request to our engineering department, which is always available for advice on special problems.



DEPENDABLE RELAY CO LTD

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Please send me free illustrated brochure giving details of Dependable Relays

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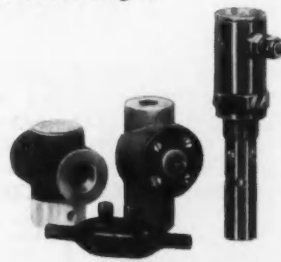
ELECTROLYTIC CONDUCTIVITY CONTROL



The Type RC4 conductivity controller and measuring bridge continuously monitors the purity of processed waters, wash and rinse waters, steam condensate, effluent concentration etc. and operates electrical ancillaries such as magnetic valves and visual or audible signals, when the conductivity reaches a predetermined value.

A wide selection of patented, indestructible measuring cells, which have precise and interchangeable electrical constants, are available for use with the controller under a variety of conditions. Extremes of pressure and temperature up to 3,000 p.s.i. and 200°C are catered for.

Plastic bodied, non-metallic cells are invaluable for use with extremely pure water in which the complete absence of leaching is essential.



Descriptive leaflet available upon request



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(LONDON) LTD.

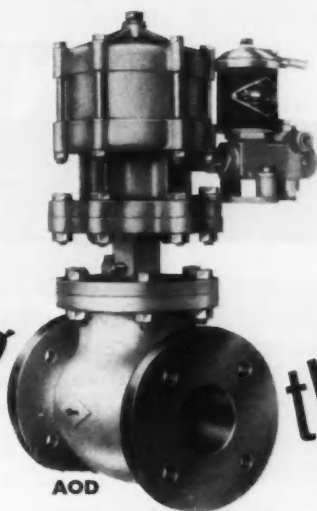
LETCWORTH · HERTS · TEL: 1853

ELECTROLYTIC CONDUCTIVITY MEASURING SETS,
RECORDERS, CONTROLLERS AND CELLS · CONTROLS
FOR LIQUID AND SOLID LEVELS · TIMING · PHOTO-
ELECTRIC PACKAGING REGISTRATION · ETC.

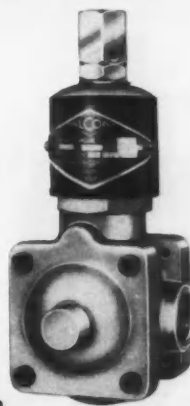
47 VICTORIA STREET, WESTMINSTER, S.W.1. ABBEY 2771/5



ACH



AOD



SPC 3

anything that flows



ACO

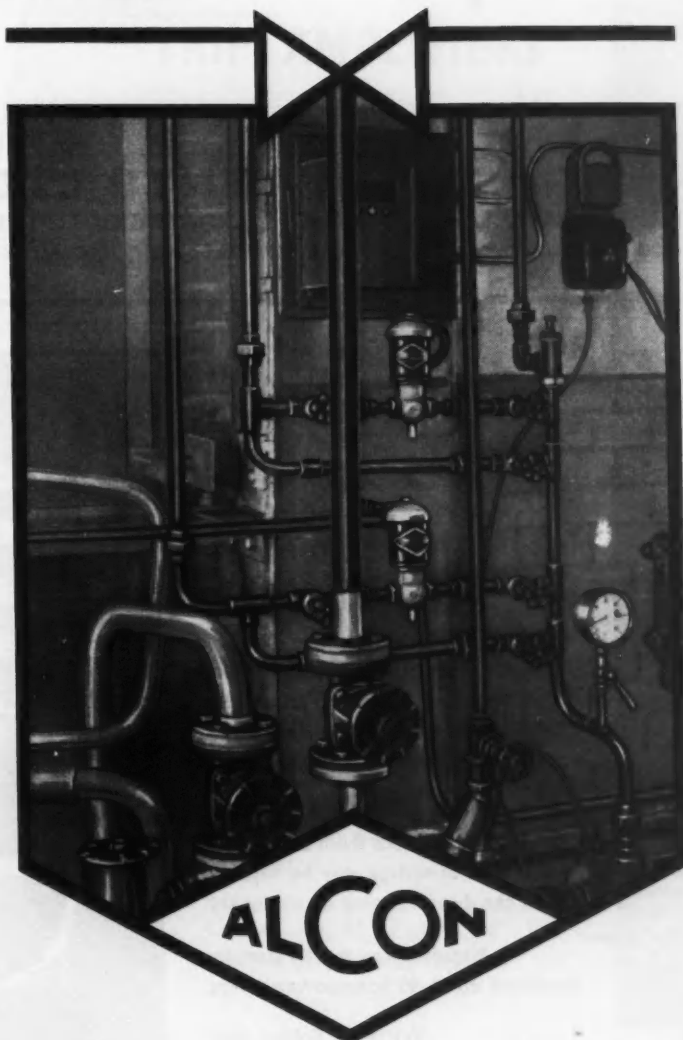
All Liquids and Gases can be positively controlled by an Alcon Solenoid or Air-operated Valve. Sizes from $\frac{1}{8}$ " B.S.P. to 8" Bore. Pressures up to 1,500 p.s.i. Temperatures up to 300°C. Body materials to suit all media including corrosive acids, with Standard, Weatherproof or Buxton Certified Flameproof Solenoid housings. Glandless, Fluon Glands or Stainless steel Bellows glands.

AIR-OPERATED Type AOD — Heavy duty air operated units individually designed for control applications beyond capabilities of Solenoid types. For pressures up to 1,500 p.s.i. Sizes $\frac{1}{4}$ " B.S.P.—8" Bore.

SPC.3—Three-way valves for electro-pneumatic control systems. Sizes up to $\frac{1}{2}$ " B.S.P. for use with air up to 150 p.s.i.

MIDGET Type ACO— Sizes up to $\frac{3}{8}$ " B.S.P., used for control of Air, Gases, Water, Oil at pressures up to 300 p.s.i. Single way—Reverse acting—three-way types available.

ACH—Hand Reset type, closing automatically on current failure, for low and medium pressures. Sizes from $\frac{3}{8}$ " B.S.P. to 6" Bore. Inexpensive, simple construction, reliable in operation. Also available type ACHL. Lever operated for use with steam, hot water and pre-heated fuel oils.



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ALEXANDER CONTROLS LTD., REDDICAP HILL, SUTTON COLDFIELD, WARWICKSHIRE
A MEMBER OF THE CONCENTRIC GROUP OF COMPANIES



TANK CONTENTS CONTROLLER

High and low level control or alarm is effectively available with the K.D.G. Tank Contents Controller. Suitably wired for pump control, warning lights, klaxons or motor starters. It requires no outside source of power for indication.

This unit is available for use with most liquids including pure foods and corrosives.

Full details and specifications of the complete K.D.G. range are readily available from:—

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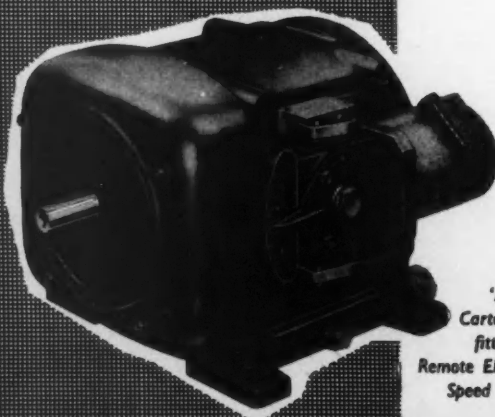
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Smooth stepless speed variation from input speed down to zero r.p.m. with accurate control by Handwheel, Remote Electrical or Lever arrangements.

Carter Variable Speed Gears may be used to pick up loads from zero r.p.m. and speed control setting may be adjusted with the drive running or stationary.

Manufactured in ten sizes for fractional up to 40 horsepower drives.

Write for Folder 1660.



'A' Type
Carter Gear
fitted with
Remote Electrical
Speed Control

Carter Gears Limited

BRADFORD 3 YORKSHIRE ENGLAND



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Otter

REGD.

WORLD PATENTS INCLUDING PATENT NUMBERS 600055 622781
624905 657434 713443 749716 774911 782648 AND OTHERS
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MINIATURE

SNAP ACTION

THERMOSTATS & SAFETY CUT OUTS

For Quartz Crystal control Radar & Electrical Equipment
Control Gear and Airborne Equipment

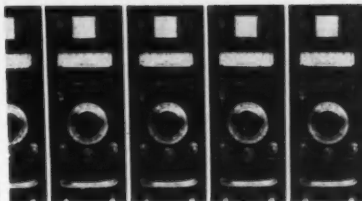
- ★ Individually and accurately factory set
- ★ Long life and stability
- ★ Robust and reliable
- ★ Up to 20 amp. 250 V. rating
- ★ TROPICALISATION—metal parts may be silver plated, and top grade insulation is used.

All Otter thermostats "Press their contacts together to open them with a SNAP!"

OTTER CONTROLS LIMITED

OTTERS' OLE, BUXTON, DERBYSHIRE
Phone Buxton 650 (2 lines)

murphy



TRIP AMPLIFIERS

for monitoring

TEMPERATURE, STRAIN,
and any low level d.c. signal.

Some salient features:

Transistorised high-speed chopper
amplifier.

Relays and lamps operate at alarm
and trip levels.

Trip margin indication with two
scales at 10:1 sensitivity ratio.

Lockable pre-set trip level control
calibrated 0—1000.

Rejects extraneous 50 c.p.s pick-up.

Incorporates all possible fail-safe
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Compact size, 8½" × 3½" × 13"
deep allows 5 units per standard
19" rack.

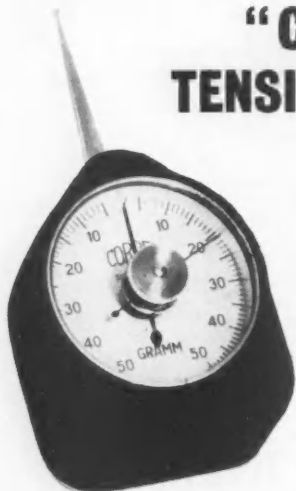
For further information please contact:

MURPHY RADIO LTD (ELECTRONICS DIVISION)
WELWYN GARDEN CITY, HERTFORDSHIRE.
TEL. No. WELWYN GARDEN 3434.

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"CORREX" TENSION GAUGES



The only instrument solely designed for accurately measuring tension on *Relays, Contacts, Switchgear*, and electrical apparatus of all kinds. Gauge measures in grammes, and a large range of sizes is produced to cover from 0.3-2,000 grammes. Swiss made and guaranteed.

Write for illustrations and prices from the Distributors throughout the U.K.

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We have been in the forefront of developing Fractional Horse Power Motors for the past 25 years in the industrial field, and are able to meet the large variations in demand.

FRACTIONAL HORSEPOWER MOTORS

from 1/250th to 1/3rd h.p.

UNIVERSAL 1/250 to 1/2 h.p.
SINGLE, SPLIT-PHASE 1/100 to 1/2 h.p. and CAPACITOR 1/80 to 1/6 h.p.
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SHADED POLE 1/160 h.p. at 1,300 r.p.m.
GEARED UNITS 0.125 to 600 r.p.m.
Torque up to 850 lb/in.



Send for illustrated leaflet No. AB57/G showing our range of motors.

FRACTIONAL H.P. MOTORS LTD
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THE
ELECTRONIC INDUSTRIES
SOLDERING TOOL
FOR THE
TRANSISTOR AGE etc.

ADCOLA
(Regd. Trade Mark)

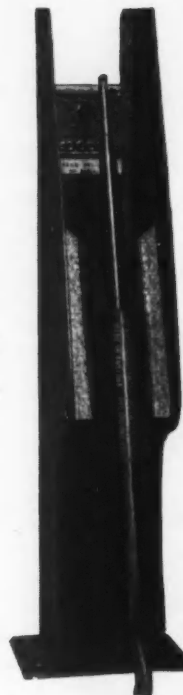
ELECTRIC SOLDERING EQUIPMENT

Manufactured in all Volt Ranges from 6/7 to 230/50 Volt with elements insulated from Earth

A PRODUCT FOR PRODUCTION
Designed for continual use on bench line assembly

BRIT. FOREIGN PATS. AND REG. DESIGNS ETC.
Standards approved in all leading countries

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1/2 BIT
MODEL
(Cat. No. 70)
PROTECTIVE
SHIELD
(Cat. No. 68)

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DRALLIM MULTI-WAY SELECTOR VALVES



201 TYPES NOW AVAILABLE
(PATENTS PENDING)

Send or phone for specification sheet No. 2
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RESEARCH BEARS FRUIT

Research into methods, research into materials enable the diversity of transformer and transduction products designed and manufactured by Aero Transformers to be continually expanded. Why not consult us now with your transformer problem.

Improved R.C.S.214 vacuum varnish impregnation process giving very low temperature gradients.



**AERO
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PULLIN

KEARFOTT

SIZE 11 RESOLVER

*for a wide range of
computing applications
and position control*

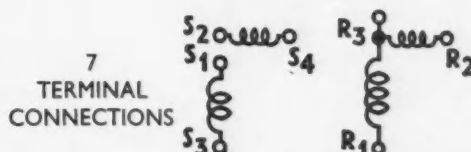
Pullin Kearfott precision resolvers to BuOrd size 11 standard with two separate phases on the stator and two phases with common terminal on the rotor.

Output is a sine and cosine expression of rotor angular position. Applications include the rotation of rectangular co-ordinates or interchange of rectangular and polar co-ordinates in computer work and precision phase shifting.



Type IIR13N4 high impedance
Type IIR2N4 low impedance

Electrical Characteristics	IIR13N4	IIR2N4
Input voltage at 400 cycles, volts	26	26
Input current, milliamps	20	52
Input power, watts	.15	.34
Transformation Ratio	0.846	0.490
Voltage gradient volts/degree	.38	.22
DC resistance rotor, ohms	200	14
DC resistance stator, ohms	130	76
Phase shift degrees	7°	10°
Residual voltage total, millivolts	58	27
Residual voltage fundamental, millivolts	38	17
Electrical Error, minutes	7 max.	7 max.



R. B. PULLIN & CO. LTD.

PHOENIX WORKS

GREAT WEST ROAD . BRENTFORD . MIDDLESEX

Cables: PULLINCO-WESPHONE LONDON Telephone: ISLeworth 1212

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SINCE 1880

Makers of Precision
Gears



All types up to 8" diameter
10 to 64 D. P.

Send your enquiries to:—

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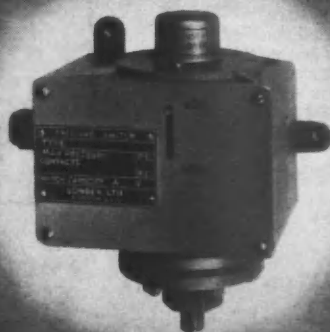
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LONDEX *Pressure
Switches*

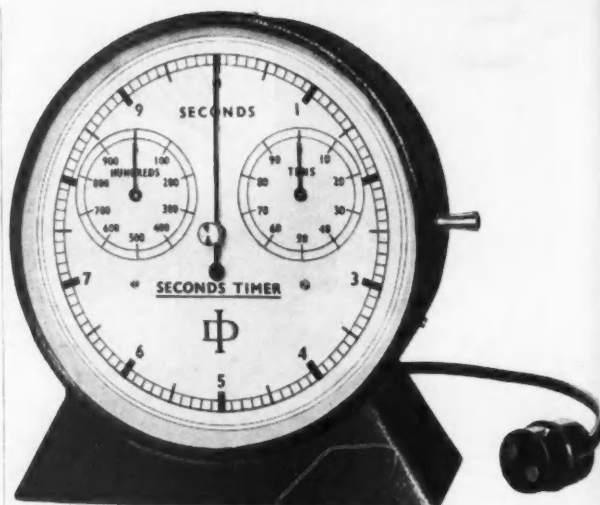
FOR ALARM CIRCUITS



LONDEX LTD LIST ON
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SECONDS TIMER

SHEWING :

Divisions of One Tenth of a Second.

Visual Record of Tens and Hundreds up to one Thousand.

Instant Start and Stop by Electrical means.

Manual Re-set to Zero.

Special Extra—Reversible Motor for Re-set.

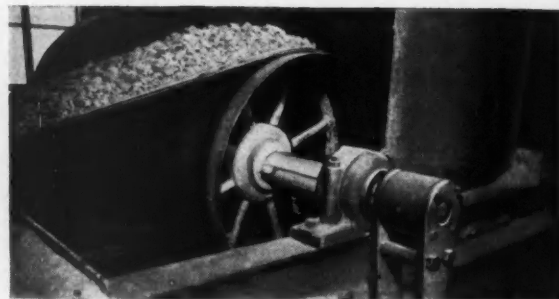
Makers of Timers of all sorts.

DEVON INSTRUMENTS LIMITED

GLOBE HALL WORKS, TOPSHAM. Topsham 3547

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RENOLD Sprag Clutches



transmit more torque for size and
weight than any other clutch

for ***BACKSTOPPING**

as illustrated on this conveyer headstock drive

***A shaft in conjunction with one
race can rotate freely in one
direction but is prevented from
reversing; there is no measurable
reverse backlash**

Write for catalogue giving
details of our comprehensive
range of over 70 standard
sizes for backstopping, in-
dexing and silent over-
running with low drag.



**RENOLD CHAINS LIMITED
MANCHESTER**

SERVICE DE RENSEIGNEMENTS POUR NOS LECTEURS

Il est souvent difficile au client publicitaire d'indiquer dans un espace restreint tous les détails de ses produits. Dans le cas où vous désireriez de plus amples renseignements à ce sujet, veuillez pointer le numéro approprié sur la carte ci-contre et envoyer cette dernière à CONTROL.

AUSKUNFTSDIENST FÜR LEBER

Es ist oft schwierig für Inserenten alle technischen Einzelheiten über ihre Produkte in einem begrenzten Platz zu bringen. Sollten Sie noch weitere Auskünfte wünschen, streichen Sie einfach die bestimmten Nummern auf der nebenstehenden Karte an, und senden Sie sie an CONTROL.

SERVIZIO D'INFORMAZIONI PER I NOSTRI LETTORI

E' talvolta difficile all'inserzionista di indicare in uno spazio ristretto tutti i particolari dei suoi prodotti. Qualora desiderate ricevere più ampie informazioni a questo riguardo, favorite segnare il numero appropriato sul cartellino qui accanto ed inviare quest'ultimo a CONTROL.

SERVICIO DE INFORMACIÓN PARA EL LECTOR

Se hace a menudo difícil para los anunciantes dar en un espacio limitado todos los detalles técnicos sobre sus productos. Si desea ulterior información, marque los números apropiados en la tarjeta opuesta y mándela a CONTROL.

Информация для читателей

Часто бывает трудно рекламующим лицам давать все технические подробности своей продукции в рекламе. Если Вам понадобятся дополнительные сведения, то просто отметьте соответствующие номера на картоне на противоположной стороне и отправьте их CONTROL.

讀者詢問服務

在廣告上以有限的地方來解釋一些專門技術及它們的動向，的確是有更限制的困難。查詢者欲得知一些詳細的情況，就請將對應的號碼，取一張下來，將閣下有疑問的項目，用筆勾一勾，寄給讀者服務工程處即可。

讀者サービス

廣告版面の關係上、製品の技術的細目は掲載しきれませんので詳しくは資料カードの通函をランペーに印をつけて原稿を宛先まで下さればお答へします。

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April 1960

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SURVEY

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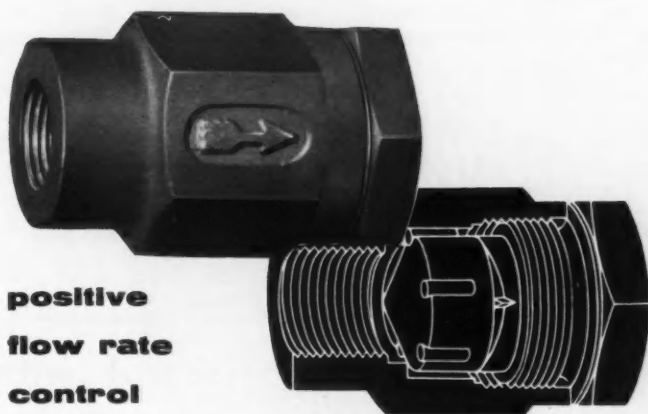
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BIRFLO controls

for positive and precise
regulation of hot or cold water,
light oils and air.

Constaflo CONTROL



**positive
flow rate
control
for**

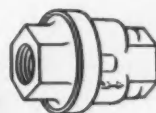
water-oil-air The "Constaflo" is designed to deliver one set rate of fluid flow regardless of variable inlet pressures between 10-200 lbs. p.s.i. It automatically measures a predetermined amount of flow regardless of variable pressures and eliminates unnecessary waste. A fixed rate of outlet flow is assured as the flow is regulated in direct proportion to the inlet pressures exerted against the diaphragm. The "Constaflo" is available in three sizes, to cope with rates of flow from .1 to 7 g.p.m., it is of high quality non-corrosive bronze, and is both durable and reliable. The "Constaflo" can be used with a timing device for measuring quantities, subdues pressure hammer and flow surges, and reduces maintenance of appliances and equipment. The "Constaflo" is one of seven Birflo controls, each designed to solve flow problems.

Made under licence from the
Hayes Manufacturing Co., Erie 6, P.A.

product of **BIRFIELD**

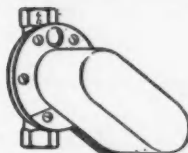


GROUP experience and resources



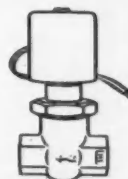
MULTI CONSTAFLO

An accurate
metering valve
for flow rates
up to 86 g.p.m.
Sizes $\frac{1}{2}$ " & 2".



TRUFLO

For positive
flow-rate control
with minimum
(0.1 g.p.m.) or
maximum (40 g.p.m.)
limits.



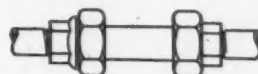
FLOMAX

A solenoid valve
for maximum
flow rates.
Sizes up to
1 $\frac{1}{2}$ " B.S.P.



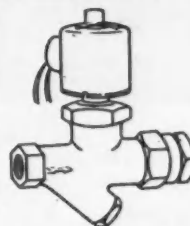
FLOMITE

A direct acting
solenoid valve for
small flow and
volume control.
Sizes $\frac{1}{4}$ " and $\frac{1}{2}$ "



STRAITFLO

A straight line strainer, installed in the
supply, having the entire strainer area
within the flow way itself. Sizes up to 1 $\frac{1}{2}$ "



FLOMETRIC

Solenoid valve
combining
consistent flow
control with
filter protection.
Flow rate from
 $\frac{1}{2}$ g.p.m. to
4 $\frac{1}{2}$ g.p.m.

Fully informative leaflets on all the
Birflo Controls are available on request.

Enquiries to: **LAYCOCK ENGINEERING LIMITED** • MILLHOUSES • SHEFFIELD 8

CONTROL April 1960

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183

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ELECTRICAL REMOTE CONTROL CO. LTD.

Manufacturers of Electrical Timing and Control Apparatus

- * Range of fully automatic process timers for AC and DC.
- * Range of cam operated hand reset process timers for AC and DC.
- * Multiple contact and mercury relays for AC and DC.
- * Special purpose control panels to customers' requirements.



Miniature automatic synchronous timer type ZX 1-12 continuously adjustable independent timing circuits with or without time setting dials. Timing ranges between 0-30 seconds and 0-28 days. Switching capacity 10 amps at 230 v AC. Overall dimensions of 2-circuit unit 2½" x 3¼" x 5½"

HARLOW, ESSEX

Tel.: Harlow 24285

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This is it!



AT LAST, a sensible Diode Tester at a sensible price, small yet robust and packed with practical ideas.

- * Will test all semi-conductor diodes, including Zener types.
 - * The diode, once connected, need not be touched until its complete characteristics have been taken.
- D.C. RANGES COVERED:
- * Current: 5 amps to 50 micro-amps full scale. Voltage: 3 volts to 1200 volts full scale. Four position switches with visible indicator give maximum safety.
 - * Both voltage and current ranges can be tailored to individual requirements.

'Phone Walton 21302/3 or write for full specifications to

R. E. THOMPSON & CO (Instruments) LTD

HERSHAM TRADING ESTATE · WALTON-ON-THAMES · SURREY

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SAVE TIME! ELECTRONICALLY



(WATFORD TYPE B)

High Speed Counter and Batch Selector

Counting up to 9,999,999,999

At a rate of 4,000 c/s per sec. and batching any number from 1-10,000 at 5 batches per sec.

Input pulse can be obtained by photo-electric source, or electrical contacts, according to customer's requirements.

This Instrument is complete with change over contacts for controlling external circuits.

Less elaborate Counters and Electronic Control Equipment made to special requirements.



Precision Engineers Ltd.

COLONIAL WAY · STATION ESTATE

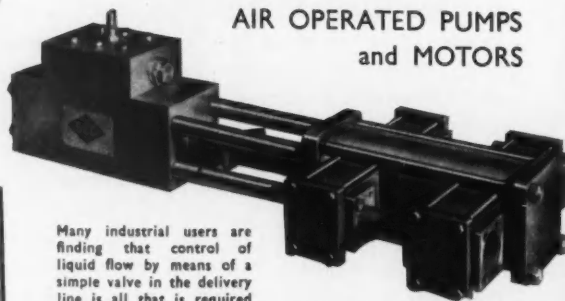
WATFORD · HERTS.

Telephone: WATFORD 26259

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Simplified Control with NEUMO

AIR OPERATED PUMPS and MOTORS



Many industrial users are finding that control of liquid flow by means of a simple valve in the delivery line is all that is required when using Neumo positive displacement air operated pumps. This valve may be at any distance from the pump enabling operators to control pumps at distant points of delivery. The system is reliable because no extra control gear is employed, the pump merely stalling by back pressure in the delivery line and recommencing delivery upon release of the pressure. The possibility of raising undue pressure in the line is avoided by automatic over-load devices in the pump which can be set to come into action at a predetermined pressure. Pumps are made in a wide variety of materials to cope with all liquids. Neumo motors containing only two moving parts are a safe, reliable means of obtaining reciprocating motion and again may be stalled without damage.

Write for further details to:

NEUMO LIMITED

South Coast Road, PEACEHAVEN, Sussex.

Telephone: Peacehaven 2115 & 3354.

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BURGESS



MINIATURE MICRO SWITCHES AND ACTUATORS

PLEASE ASK FOR MORE DETAILS

There are many other Miniature Micro Switches and Actuators besides the few illustrated here. All have the famous BURGESS long-life mechanism.

BURGESS PRODUCTS COMPANY LTD

MICRO SWITCH DIVISION

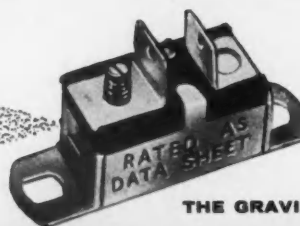
Dukes Way, Team Valley, Gateshead 11.
Telephone. Low Foll 75302 (3 lines) Telex: 53-228
London Office: 127 Victoria Street, S.W.1.
Telephone. TATE Gallery 0251 (3 lines)

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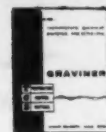
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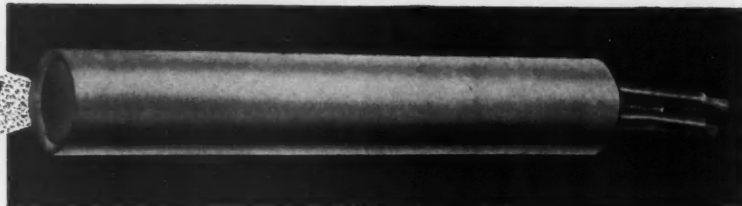
Pin-point Automatic Accuracy



THE GRAVINETTE



Write for
Catalogue G. 100
Temperature Control
Switches



THE GRAVINETTE

A miniature precision unit for Surface Mounting, to provide for optimum temperature control on applications where space is at a premium. The Gravinette is an adjustable unit and is offered in four versions:—

- Type TCS 3150, normally closed, range—70°C to 100°C,
- Type TCS 3151, normally open, range—70°C to 100°C,
- Type TCS 3250, normally closed, range 40°C to 250°C,
- Type TCS 3251, normally open, range 40°C to 250°C.

T TEMPERATURE

Normal rating 1 amp. on 250v A.C., and 2 amps on 28v D.C.

C CONTROL

S SWITCHES

CARTRIDGE TYPE SERIES 1000, TENSION OPERATED

These precision temperature control switches are designed primarily for use in heater blocks, heated plates and similar applications where excessive moisture or vapour is not present. Possessing the desirable features of the ideal thermostat, the Graviner Temperature Control Switch is of convenient size and shape, adjustable and resistant to vibration and shock, and easy to install.

Current Rating 5 amps 250 v. A.C. for standard types.

For further details of our complete range write or telephone

GRAVINER • COLNBROOK • SLOUGH • BUCKS

Telephone: Colnbrook 2345

Specialists in Airborne and Industrial Fire and Explosion Protection, Nuclear Development and Production Engineering

Keep those Contacts CLEAN

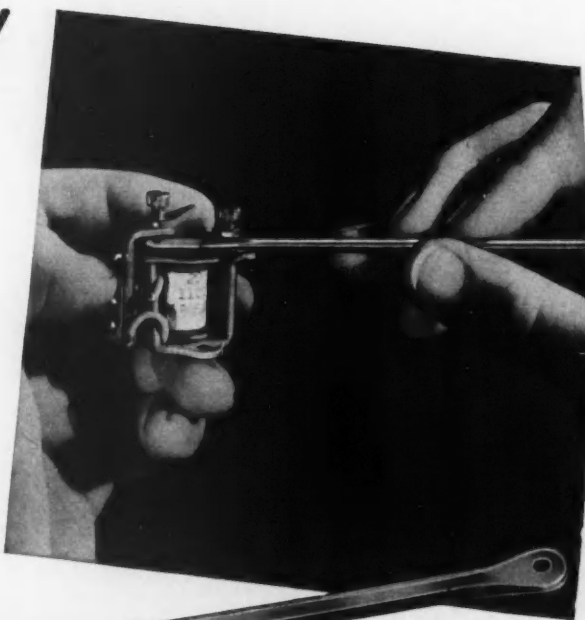
by using a

SEPI

DIACROM SPATULA

The "Diacrom" is a metal spatula upon which diamond powder has been deposited by a special process. No deep scratches are possible because density is controlled and the polishing of the contacts is achieved by a gentle brushing motion. With coloured nylon handle for complete insulation and easy size identification.

- Grain size 200, thickness 55/100 mm., both faces diamonded. For quick cleaning of industrial relays and switching equipment, etc.
- Grain size 300, thickness 55/100 mm., both faces diamonded. For smaller equipments, like telephone relays, computer relays, etc.
- Grain size 400, thickness 25/100 mm., one face diamonded. For sensitive relays and tiny contacts. Two close contacts facing each other can be individually cleaned, because only one face of the spatula is abrasive.



Actual size of Spatula



Sole Distributors for the United Kingdom

Manufactured in France
British Patents applied for.

S. GUTERMAN & CO. LTD • 37 SOHO SQ., LONDON W.1 • Phone: GERRard 2571

As supplied to the War Office, U.K.A.E.A., Electricity Generating Boards, British Railways, and other public authorities and also to leading electronic and industrial users throughout the United Kingdom

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FORTIPHONE

TRANSFORMERS



are chosen by the

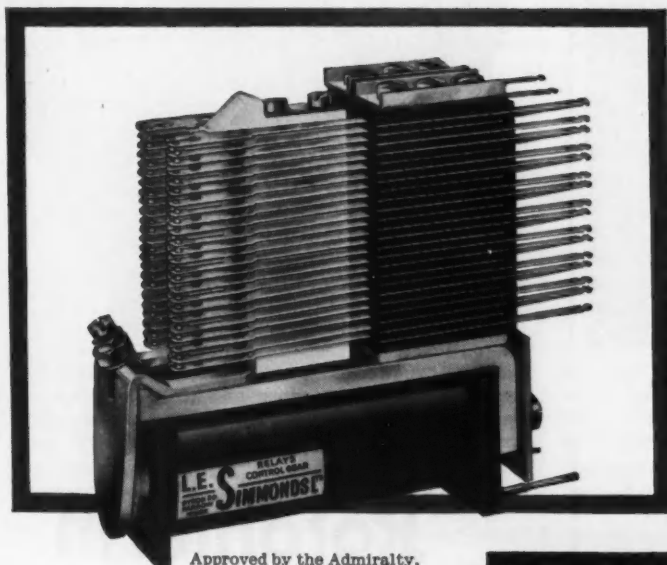
TRIX ELECTRICAL CO. LTD. for use in their

TRIXADIO PASSENGER ANNOUNCEMENT SYSTEM

fitted in Comet Jet Airliners

FORTIPHONE TRANSFORMER DIVISION (DEPT. 3) 92 MIDDLESEX ST. LONDON E.1.

Relays to specification



POST OFFICE TYPE 3,000 AND 600 RELAYS

A NEW DEVELOPMENT—illustrated here is our P.O. Type 3,000 Relay with sixteen changeovers with Light Duty Silver or Platinum Contacts. **P.O. TYPE 600 RELAYS** with Heavy Duty Contacts rated at 8 amps. also available. Complete range of both types manufactured to specification. Prototypes 24 hours. **P.T.F.E.** insulation now available. Specialists in **TROPICAL FINISHES**. Guaranteed to full **A.I.D.** and **I.E.M.E.** standards.

Approved by the Admiralty,
Post Office and U.K.A.E.A.
All relays guaranteed made
in our own works.

SIMMONDS

Manufacturers to H.M. Government Departments and leading Contractors.

L. E. SIMMONDS LTD., 5, BYRON ROAD, HARROW, MIDDLESEX. TEL: HARROW 7797/9 TELEGRAMS: SIMRELAY HARROW

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really gripping...



NEWTON
TRADE PRODUCT MARK

... it pays to install

Hydraulic CLAMPING

- * Manual Hydraulic, Motorized Hydraulic or Air Hydraulic
- * Plungers from ½ Ton thrust (1½" outside dia.) to 4 Tons thrust (3" outside dia.)

POWER JACKS
LIMITED

Pipe fittings for all sizes also available

Write for Brochure F4/243

VALETTA ROAD, ACTON, W.3.

Telephone: Shepherds Bush 3443/6 Telegrams: Newsorber, Ealux, London

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MERCURY SWITCHES



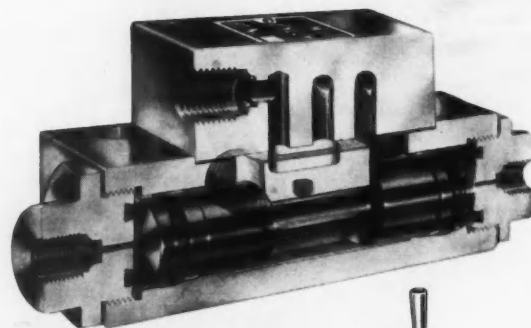
ONE OF OUR RANGE OF OVER
1,650 TYPES FOR ALL PURPOSES

ALSO MERCURY SWITCH UNITS FOR
HAND OR MECHANICAL OPERATION
AND MERCURY SWITCH RELAYS

I.A.C. LTD., Ref. C., 10 CHASE ROAD,
LONDON, N.W.10

Telephone ELGAR 7281 & 7285

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MILLIONS MORE valve reversals

exclusive new
development
INCREASES VALVE LIFE
many times

Valve slides moulded from FLUON* are exclusive to the range of Midland Pneumatic "FLUOSLIDE" Control Valves. Having a coefficient of friction equalled only by wet ice on wet ice such slides give millions more valve reversals. All other working parts made from bronze or stainless steel. Range 1" - 1" B.S.P. Short delivery. Also a complete range of cylinders from 1" to 10" bore, cushioned and non-cushioned. Send for catalogue.

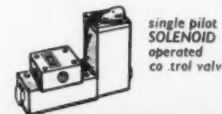
*Regd. Trade Mark—I.C.I. LTD.



hand control valve



single pedal foot valve



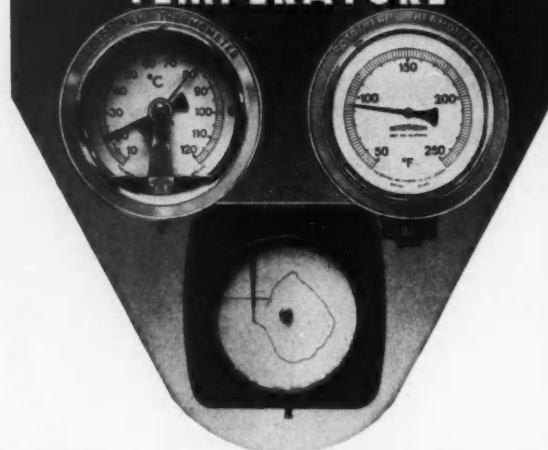
single pilot SOLENOID operated co. rol valve

MIDLAND
PNEUMATIC LTD
NEW CROSS - WOLVERHAMPTON

Telephone: 32501-2

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TO INDICATE CONTROL OR RECORD TEMPERATURE



For accuracy, ease of reading, robustness, economy and long, trouble free life install Rototherm Thermometers, Controllers and Recorders. Specialists in bi-metallic applications.

Write for details.

Rototherm

BI-METAL MERCURY-IN-STEEL VAPOUR PRESSURE
THE BRITISH ROTOTHERM CO. LTD.
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Midland Factory: Hollis St., New Basford Nottingham 77047

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hermetic seals

standard types supplied



Enquiries to
**SINTERED GLASS TO
METAL SEAL CO LTD**
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to see what

GORDON

can do!

**FUEL EFFICIENCY AND POWER
FOR INDUSTRY EXHIBITION
OLYMPIA, LONDON**

27th APRIL TO 6th MAY 1960

STAND NO. 7

ROW A

**INSTRUMENTS, ELECTRONICS AND
AUTOMATION EXHIBITION
OLYMPIA, LONDON**

23rd TO 28th MAY 1960

STAND NO. 155

ROW D

**Do not fail to visit us at our stand and see for yourself how Gordon instrumentation and control
can increase efficiency in your boiler plant.**

Automatic combustion control, pneumatic or electronic, for boilers and furnaces of all types and sizes. Temperature control for superheated steam temperatures. Steam desuperheaters and reducing, overflow and relief valves for regulating pressures and temperatures in chemical processes and turbine

bypasses. Complete boiler plant instrumentation including indicating and recording instruments for CO₂, pressure and vacuum, temperature, flow, liquid level, B.T.U., etc. Igema distance boiler water level indicators. Mono automatic gas analysis recorders for CO₂, CO, H₂, O₂, SO₂, H₂S, etc.

Tickets available on request.

JAMES GORDON & CO. LTD

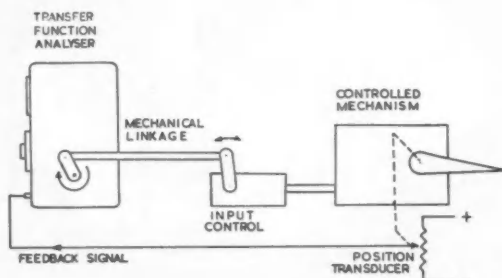
Dalston Gardens, Stanmore, Middx.

Telephone: Wordsworth 3631

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HYDRAULIC SERVO TESTING

*Made easy and accurate
with Servo Consultants'
Transfer Function Analys-
ers and Automatic Nyquist
Plotters.*



These versatile instruments may also be used for:

- * AC Servo Testing
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We also manufacture Very Low Frequency Generators, Process Analysers and a Standard Range of Servo Gear-boxes.

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10 Bouverie Place, London, W.2. Tel. PAD 2811

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Type LP 2

PENNY & GILES

MUDEFORD • CHRISTCHURCH • HANTS
TELEPHONE HIGHCLIFFE 2855

RECTILINEAR POTENTIOMETERS

FOR REMOTE INDICATION AND
RECORDING OF DISPLACEMENT

STROKE LENGTHS

Up to 9 inch for Type LP 2
Up to 24 inch for Type LP 1

TWO RESISTANCE ELEMENTS

AMBIENT TEMPERATURES

Available for use in the following ranges
-50°C to +85°C
-50°C to +150°C
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RESOLUTION of 0.001 inch can be achieved

WRITE FOR DATA SHEETS

Also manufacturers of potentiometers in size 11
and size 15 synchro mountings.
Single and multi-gang. Single and multi-turn.

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Lock

Portable

CONDUCTIVITY BRIDGE

TYPE BC I

Fully transistorised, it operates at 1500 c/s from a small long-life dry battery. It covers the wide range of 0.5 to 1×10^6 micro mhos in six ranges.

A mains-operated bridge is also available. It covers the range of 0.05 to 1×10^6 micro mhos.



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PRUDENTIAL BUILDINGS, OLDHAM, LANCASHIRE.

Tel: MAIn 6744

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50 c.p.s. SERVO MOTORS

RANGE:—40, 60, 90, 150 oz. inches stalled torque. With magnetic amplifier control units, tachometer generators and gearboxes if required.

by

WALTER JONES

—a fine range
of small power electrical
rotating equipments.

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A SENIOR SYSTEMS DESIGN ENGINEER

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INST. No.	IAS	WOP	N	O	Q	R	S	A	B	C	NARRATIVE
700	20	0	0	0	0	7	4				Transfer Xals to Register 4. Test if any inputs.
701	42	7	0	3	4	0	0	0	0	0	
703	20	0	0	0	0	0	0	0	0	0	
704	41	7	6	7							
705	24	4	0	1							
706	42	7	0	7							
707	20	4	0	1							
708	24	4	0	1	0	4	7	2	7	0	Test if Xals 13-4.
709	42	8	4	2	7	1	0	8	4	2	(34 jump and from program)
710	20	4	0	1	3	0	5	0	7	3	Test if Xals 13-4.
711	24	4	0	1	6	4	6	3	7	0	Test if Xals 13-4.
712	20	4	0	1							
713	24	4	0	1							
714	20	4	0	1							
715	24	4	0	1							
716	20	4	0	1							
717	24	4	0	1							
718	32	6	6	4	8	5	0	8	8	1	Merge with form "Multiplication Routine" "Jump to that routine"
719	40	0	0	0	8	4	4	0	0	0	

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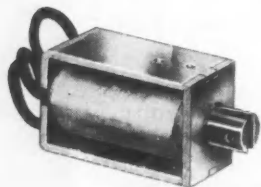
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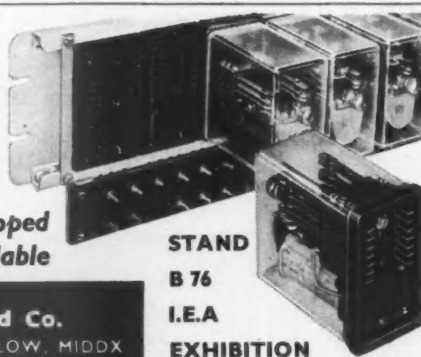
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application of automatic control and to afford opportunity for study of
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dates should hold a degree in Engineering or a suitable alternative
qualification and have had some practical training and experience. They
may be required to attend for interview in Cambridge.

Further details and forms of application for admission may be
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Shaft diameter, inches (nominal)	1/4	1/8	1/4	1/4	1/4	1/4	1/4
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Max. starting torque, oz. in.	2	0.7	1.8	3.5	0.7	1.7	1.3
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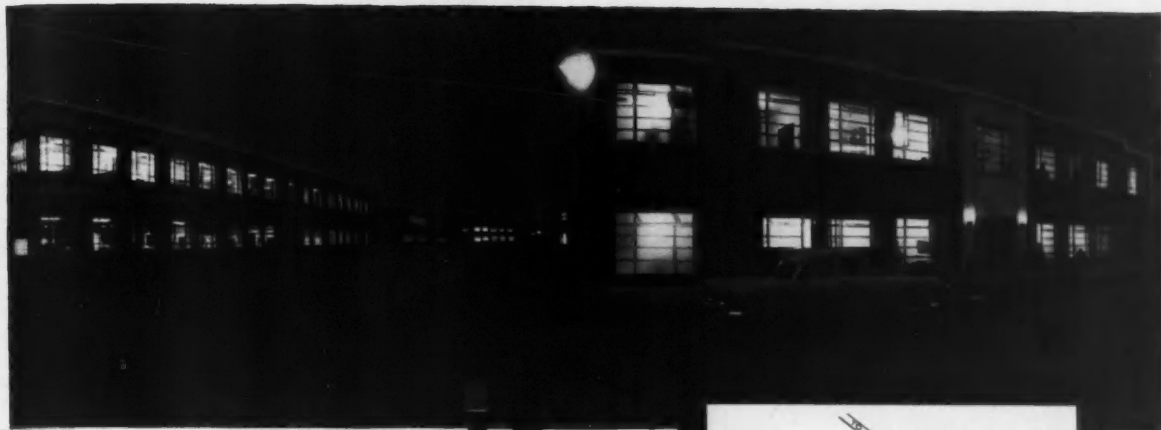
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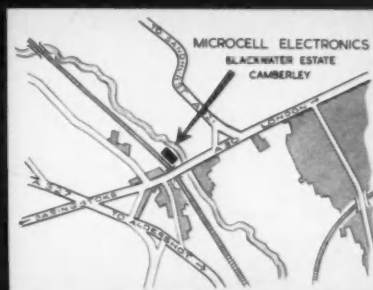
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